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ADVANCED THRUST VECTOR CONTROL PRELIMINARY DESIGN COMPUTER PROGRAM

Volume II User's Manual

THIOKOL / WASATCH DIVISION

A DIVISION OF THIOKOL CHEMICAL CORPORATION

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AIR FORCE ROCKET PROPULSION LABORATORY
EDWARDS AIR FORCE BASE, CALIFORNIA

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FOREWORD

The ASC/TMC Preliminary Design Computer Program for air and surface launched missiles was developed under Contract F04611-71-C-0013 by the Thiokol Chemical Corporation, Wasatch Division, Brigham City, Utah. The program was started on 1 October 1970 and completed on 1 September 1972. The Air Force Project Monitor was Lt Louis Fox, MKCD.

Wasatch Division personnel who contributed significantly to development of the computer program and to preparation of this final report are identified in the following tabulation.

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This technical report has been reviewed and is approved.

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UNCLASSIFIED ABSTRACT

This final report documents work accomplished under contract F04611-71-C-0013. The program discussion describes the intent and capabilities of the computer program which was developed to (1) evaluate preliminary duty cycles for missile systems, (2) develop specifications for the control system being employed, (3) perform preliminary design analysis on any of the control options, and (4) predict the performance capability of a vehicle utilizing the control system characteristics obtained from the program. The seven potential control inputs are liquid injection thrust vector control, hot gas thrust vector control, gimbal ring, ball and socket, flexible seal, jet tabs, and aerodynamic surfaces. The program has the capability to determine the thrust magnitude required to fly any one of the six types of trajectories where thrust vector and thrust magnitude control is required. The nozzle design capability includes two types of fixed nozzles and five types of movable nozzles. The program also incorporates design capability for pintle nozzle single chamber thrust magnitude control with or without thrust vector control. Two material options are available for case design, metal and filament wound glass. A three dimensional six degrees of freedom trajectory routine is available in the program.

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I. INTRODUCTION

This user's manual is provided to assist in preparing input data and interpreting the output of the ASC/TMC Computer Program.

The manual first discusses the overall program logic and how to specify which portions of the program are to be executed. The method of input utilized by the program is discussed including examples. The input requirements are presented for each portion of the program, along with a sample input and resultant program printout.

II. PROGRAM LOGIC

A. PROGRAM FLOW

Figure 1 contains the macro flow chart of the ASC/TMC computer program flow control logic.

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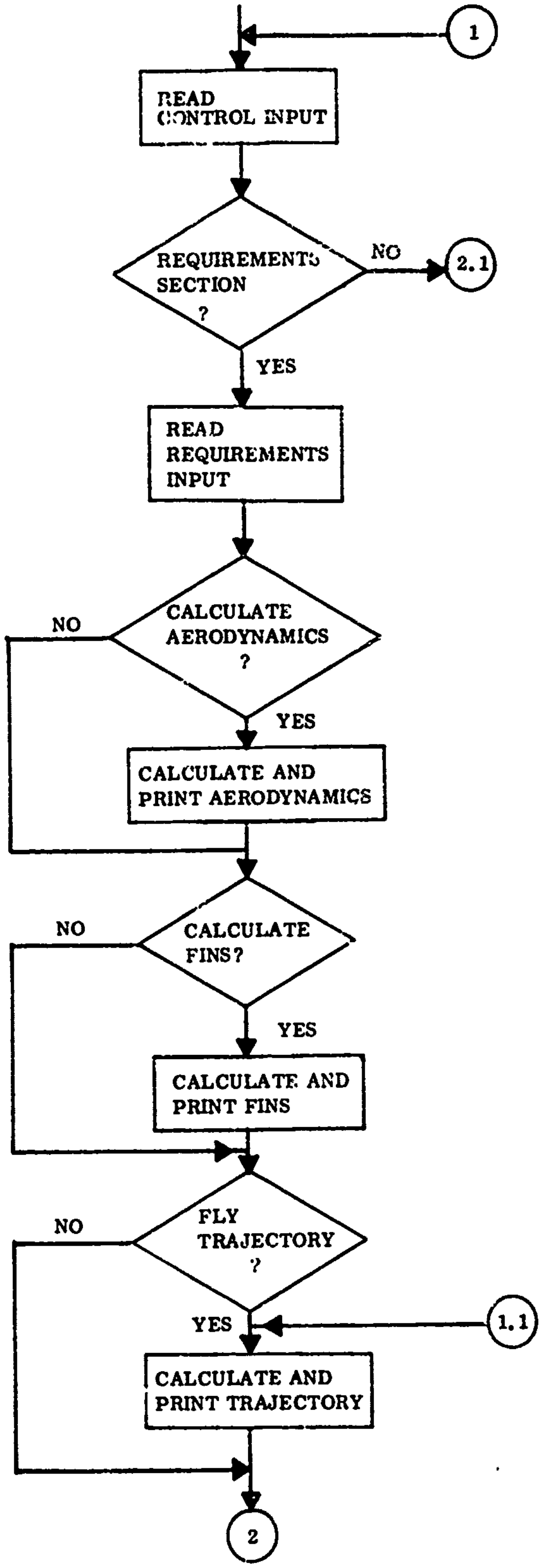

Figure 1. Program Flow (Sheet 1 of 4)

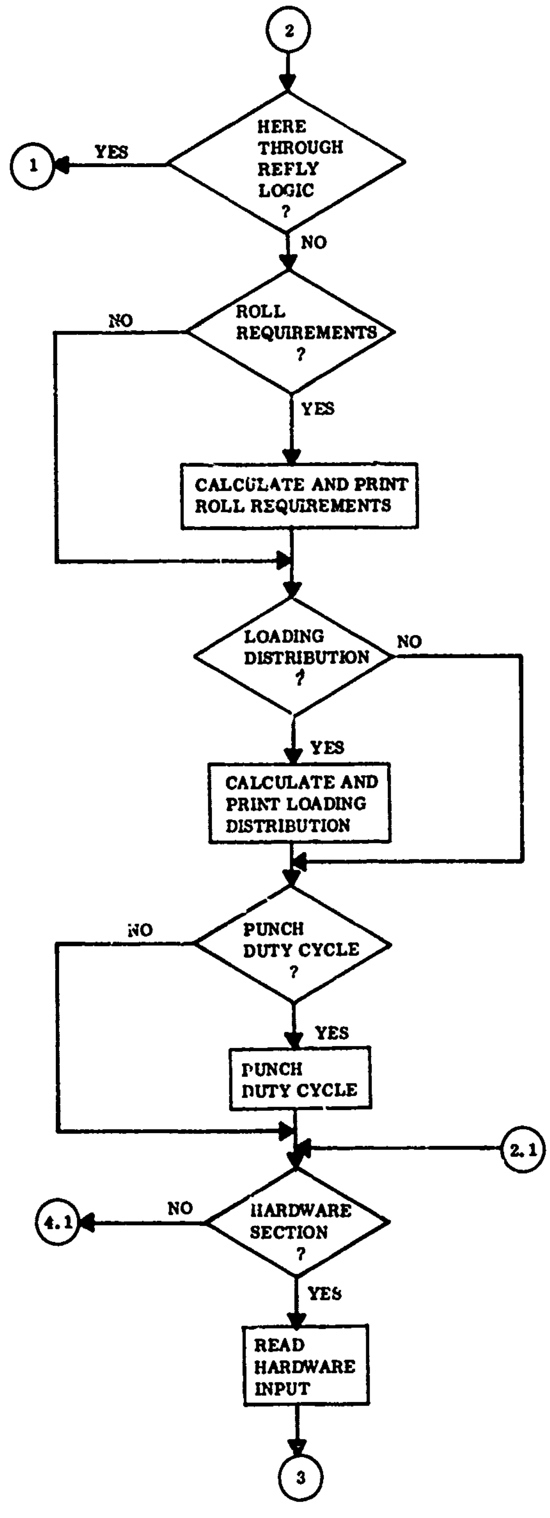

Figure 1. Program Flow (Sheet 2 of 4)

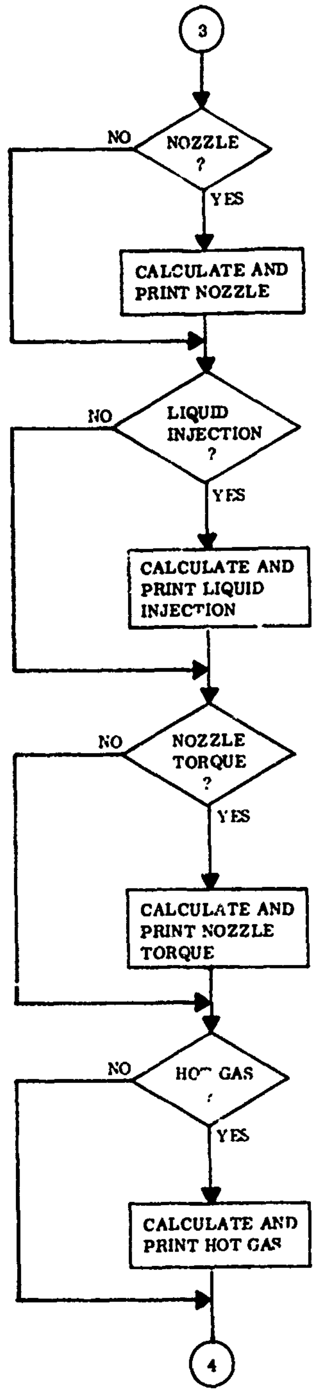

Figure 1. Program Flow (Sheet 3 of 4)

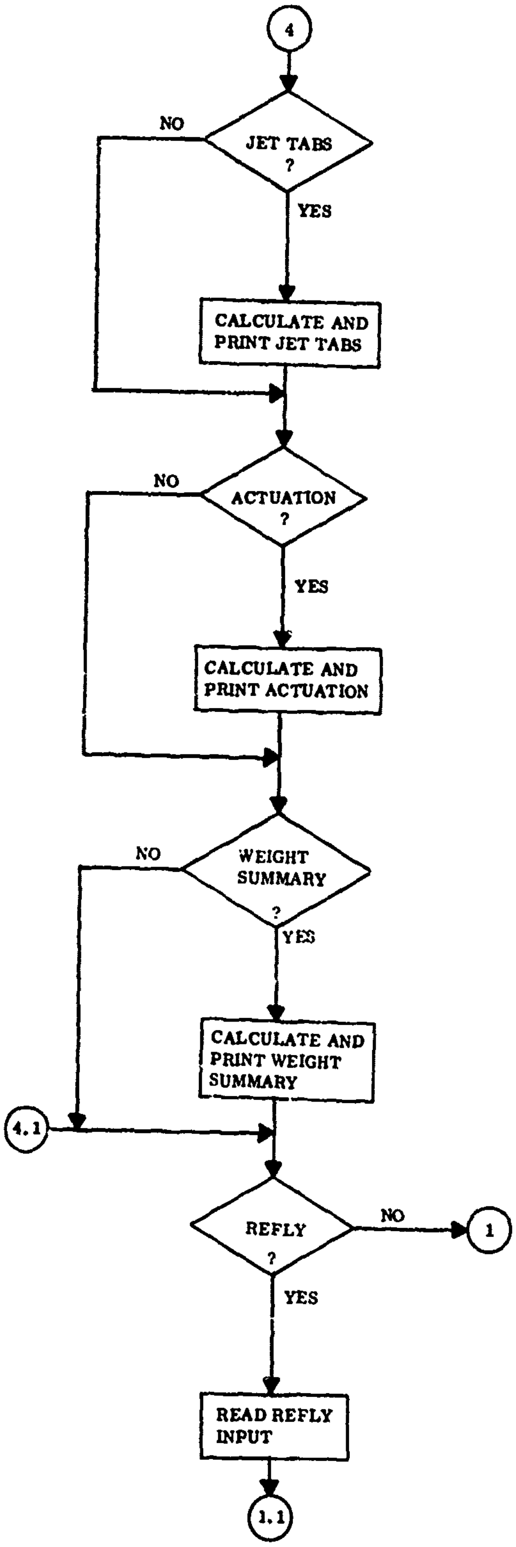

Figure 1. Program Flow (Sheet 4 of 4)

B. CONTROL INPUT

The first input card for each case is a control card which specifies by a control flag what program subroutines are to be executed.

A flag may be input in each even column of the card from column 2 through 32, namely 2, 4, 6, 8 . . . 32.

The flags are divided into three groups:

1. Columns 2, 4 and 6 control execution of the three major sections of the program.

2. Columns 8 through 18 control execution of the requirements section of the program.

3. Columns 20 through 32 control execution of the hardware section of the program.

TABLE I

1. PROGRAM EXECUTION FLAGS

Column	Section
2	Requirements Section
4	Hardware Section
6	Refly Logic Section

Value	Definition
0 or blank	Do not enter this section of the program.
1	Enter this section of the program. Read a set of input followed by a T-card and execute the portions of this section as requested. The input storage locations will not be reset to their initial default values; therefore, only values which change from a preceding case for this section need be input.
2	Do the same as 1, above, except reset the input storage locations to their initial default values.

TABLE I (Cont)

2. REQUIREMENTS FLAGS

Column	Portion of Requirements Section
8	Trajectory Simulation
10	Aerodynamic Coefficients
12	Aerodynamic Lifting Surfaces
14	Roll Control Requirements
16	Punch Duty Cycle
18	Aerodynamic Loading Distribution

Value	Definition
0 or blank	Do not enter this portion of the Requirements Section.
1	Enter and execute this portion of the Requirements Section.

TABLE I (Cont)

3. HARDWARE FLAGS

Column	Portion of the Hardware Section
20	Nozzle Design
22	Liquid Injection Performance and Actuation
24	Hot Gas
26	TVC Actuation, Roll System, and TMC Power Supply
28	Nozzle Torque
30	Jet Tab
32	Weight Summary

Value	Definition
0 or blank	Do not enter this portion of the Hardware Section.
1	Enter and execute this portion of the Hardware Section.

Following is a list of what hardware flags are usually specified for the types of thrust vector control (TVC) available.

Card Columns

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	TVC
			2																1						1		1				1				Movable Nozzle
			2																1		1				1						1				Liquid Injection
			2																1				1		1						1				Hot Gas
			2																1						1					1	1				Jet Tabs
			2																1						1						1				No TVC

SECTION III

REQUIREMENTS

A. INPUT

The Thiokol input routine (CTINP) used in this program is a versatile non-card-column oriented input subroutine. It permits a variable field input in that specific separation characters are sufficient to distinguish the individual input data items. The capabilities of the routine are described below.

1. Blank card columns are ignored, except when reading Hollerith data.
2. Data can be entered in card columns 1 thru 72. Columns 73 thru 80 are ignored.
3. Separate numerical input is distinguished from other similar input by the use of its associated sign "+" or "-" and/or a comma",". The following three examples are equivalent:

   +4, +3, -2, +5.0

   +4, 3, - 2, 5

   +4, +3, -2 +5
4. Numerical information for the TVC design program can be input as a normal decimal number (i.e., 1.20, 0.35 or 17), or as a decimal number scaled by a power of 10. The character "E" is used to indicate scaling by a power of 10. A scaled number is written in two parts. The digits preceding the "E" form the basic number. The numbers following the "E"

define the power of 10 by which the basic number is to be multiplied. For example, the number 1.5421 can be written in many ways; the following are some of the possibilities using the "E" format.

Example: 1.5421 = 0.15421 E 01 = 1542.1E-03

5. Control information is relayed to the input routine through the use of the characters "L" and "T".

   a. The character "L" indicates to the input routine that a starting location for storing data is to be established.

      Example: L22 + 4-3

      This example would cause the routine to store normalized floating point binary equivalents of +4 and -3 in relative locations 22 and 23, respectively.

   b. The character "T" signals to the input routine that the end of a loading sequence has occurred. The "T" must appear in column 1 of a card. Hollerith information contained on the "T" card will be placed in core. The TVC design program will print the Hollerith information on the "T" card on the top of each page of the output.

   c. If sequential parameters are being input, only the L-number associated with the first parameter need be designated. However, once the sequence format of the input parameters is broken, a new L-number must be designated.

An example of the CTINP routine options utilized in the TVC design program is given in the following illustration.

Assume the following information is to be loaded into the relative locations given.

Relative Location	Data
10	2.0
11	17.6
12	-24.3
17	18.1
18	0.001
24	4390000

The two sets of data shown below are equivalent and represent only two of many approaches that could be taken.

```
L10  +2   +17.6  -24.3  L17  +18.1  +.001  L24  +4390000
T    THIS CARD SIGNALS END OF DATA SEQUENCE

     DATA SET 2
L10  +2., 17.6, -24.3
L17  +18.1  +1E-3      L24  +.439E7
T ANY MESSAGE PUNCHED HERE WILL BE PRINTED ON OUTPUT
```

1. Duty Cycle Input

Duty cycle data are required in three portions of the Requirements Section.

1. Roll control requirements.
2. Punch duty cycle.
3. Aerodynamic loading distribution.

Duty cycle data are also required for the Hardware Section.

These data may be obtained in three ways.

1. By executing the trajectory simulation portion of the program, the duty cycle data will be stored in the proper location and need not be input.
2. Supplying the duty cycle with the Requirements Section input.
3. For the Hardware Section, the user may select Number 1 or 2 above, or supply the duty cycle input with the hardware input.

In the time dependent portion of the duty cycle, discontinuous points may be input by following two rules.

1. The point at which a discontinuity occurs must be input twice.
2. The number of points between discontinuities must be three or more, including the discontinuous points.

Example:

Time	Deflection Angle
0	0
2	1
4	2
4	4
6	4
8	4

The minimum number of points in the time dependent portion of the duty cycle is three.

The following parameters are input for the duty cycle.

L-No.	Symbol	Definition	Units
7000	$\bar{I}$	Motor thrust impulse for TVC duty cycle stage.	lb-sec
7001	$\bar{I}_v$	Motor vacuum thrust impulse for TVC duty cycle stage.	lb-sec
7002	x_e	TVC duty cycle stage thrust vector point body station.	ft
7003	x_{nf}	Body station of nozzle flange of the TVC design stage. Input in L-680.	ft
7004	δ_{me}	Design maximum vector angle for TVC duty cycle stage. Input in L-681.	deg
7005	I_{SPM}	Main table specific impulse for the TVC duty cycle stage. Input in L-(K_{dc}) 010.	sec
7006	$\bar{\omega}_c$	Slew frequency used in the TVC design stage slew rate calculation.	rad/sec
7007	$\dot{\delta}_S$	Control system design slew rate for TVC design stage.	deg/sec
7008	$\bar{\delta}_S$	Slew angle for TVC design stage.	deg
7009	$\bar{I}_p$	Pitch control thrust impulse per control motor from TVC duty cycle initiation to stage termination.	lb-sec
7010	$\bar{I}_{\dot{\delta}P}$	Integral of the pitch angular thrust vectoring velocities from TVC duty cycle stage initiation to stage termination.	deg
7011	$t_{\eta P}$	Stage time at which maximum magnitude pitch thrust vector deflection angle occurs during the TVC design stage ($\bar{\delta}_{Pmax}$).	sec
7012	η_P	Ratio of the delivered thrust (F) to vacuum thrust (Fvac) at maximum magnitude pitch TVC deflection angle ($\bar{\delta}_{Pmax}$).	dim
7013	$\bar{\dot{\delta}}_{Pmax}$	Maximum pitch thrust vector deflection angular rate, for the TVC design stage.	deg/sec
7014	$\bar{\delta}_{Pmax}$	Maximum magnitude pitch thrust vector deflection angle, per control motor for the TVC design stage.	deg

L-No.	Symbol	Definition	Units
7015	$\bar{I}_y$	Yaw control thrust impulse per control motor from TVC stage initiation to stage termination.	lb-sec
7016	$\bar{I}_{\dot{\delta} Y}$	Yaw deflection rate integral per vehicle control motor.	deg
7017	$t_{\eta Y}$	Stage time at which maximum magnitude yaw thrust vector deflection angle occurs during the TVC design stage (δ_{Ymax}).	sec
7018	η_Y	Ratio of the delivered thrust (F) to vacuum thrust (F_{vac}) at maximum magnitude yaw TVC deflection angle (δ_{Ymax}).	dim
7019	$\dot{\delta}_{Ymax}$	Maximum yaw thrust vector deflection angular rate, for the TVC design stage.	deg/sec
7020	δ_{Ymax}	Maximum magnitude yaw thrust vector deflection angle, per control motor for the TVC design stage.	deg
7021	$q\alpha'_{max}$	Product of the maximum absolute value of the dynamic pressure-angle of attack for the TVC design stage.	lb-deg/sq ft
7022	$q_{q\alpha'}$	Dynamic pressure at maximum $q\alpha'$ during the TVC duty cycle stage.	lb/sq ft
7023	$t_{q\alpha}$	TVC duty cycle stage time at maximum $q\alpha'$.	sec
7024	$C_{N\alpha q}$	Aerodynamic normal force coefficient at maximum $q\alpha'$ during the TVC duty cycle stage.	1/deg
7025	$M_{q\alpha}$	Mach number at maximum $q\alpha'$ during the TVC duty cycle stage.	dim.
7026	$\bar{\delta}_{avg}$	Average TVC deflection angle per control motor for the TVC design stage.	deg
7027	K_{dc}	Stage number of the TVC duty cycle stage. Input in L-671.	dim.
7028	D_B	TVC duty cycle stage case diameter from axial force reference area.	in.
7029	A_{FW1}	Stage I vacuum thrust to liftoff weight used in the vehicle characteristics pertinent to roll requirements.	g's
7030	t_B	TVC duty cycle stage time.	sec

L-No.	Symbol	Definition	Units
7031	F_{vave}	TVC duty cycle stage average vacuum thrust.	lb
7032	W_o	TVC duty cycle stage liftoff weight used in the roll control requirements.	lb
7033	R_{PFV}	Ratio of motor chamber pressure to vacuum thrust of the main thrust table of the TVC design stage.	1/sq in.
7034	$\bar{\epsilon}_d$	Nozzle average expansion ratio for TVC design stage. Input in L-(K_{dc}) 013.	dim.
7035	$\bar{A}_t$	Nozzle throat area for the main motor of the TVC design stage.	sq in.
7036	$\bar{\gamma}_d$	Ratio of specific heats of the rocket motor exhaust gases of the TVC design stage.	dim.
7037	P_{ca}	Action time average motor chamber pressure for the TVC design duty cycle stage.	lb/sq in.
7038	C*	Rocket motor propellant characteristic velocity for the TVC design duty cycle stage.	ft/sec
7039	W_{TVC}	Estimated TVC system fixed weight. Used in TVC design stage for the refly option. Input in L-677.	lb
7040	W_{exi}	Estimated weight of the TVC system expended weight during the TVC design stage during the original vehicle flight. Input in L-678.	lb
7041	I_{spaug}	Estimated TVC system caused specific impulse augmentation (positive) or degradation (negative). Used in trajectory TVC design program refly. Input in L-679.	sec
7044	n_m	Number of motors in the stage cluster	dim.
7045	n_c	Number of control nozzles for the cluster motor logic.	dim.
7046	Δ_{dc}	Number of TVC duty cycle t_B data points	dim.
7047	M_{hzmax}	Maximum of the absolute value pitch fin hinge torque for the TVC design stage.	ft-lb

L-No.	Symbol	Definition	Units
7048	M_{hymax}	Maximum of the absolute value yaw fin hinge torque for the TVC design stage	ft-lb
7052	$h_{q\alpha'}$	Altitude of TVC duty cycle stage maximum $q\alpha'$.	ft
7053	$P_{q\alpha'}$	Atmospheric pressure of TVC duty cycle stage maximum $q\alpha'$.	lb/sq ft
7054	$\bar{\bar{I}}_{VM}$	Integral of the vacuum thrust of the input main thrust table in the TVC duty cycle stage. Input in L-(K_{dc}) 005.	lb-sec
7055	$\bar{\bar{W}}_{MO}$	Initial main weight for the TVC duty cycle stage. Input in L-(K_{dc}) 006.	lb
7056	$\bar{\bar{K}}_{tM}$	TVC duty cycle stage, the main switching time multiplier. Input in L-(K_{dc}) 009.	dim.
7057	$\alpha_{q\alpha'}$	Angle of attack in pitch at TVC design stage maximum $q\alpha'$.	deg
7058	$\beta_{q\alpha'}$	Angle of side slip in yaw at TVC design stage maximum $q\alpha'$.	deg
7059	P_{cmax}	Maximum main motor chamber pressure in TVC duty cycle stage.	lb/sq ft
7060	$\dot{A}_{tmax}$	Pintle System required throat area rate.	in^2/sec
7061	I_{At}	Integral of the absolute value of the pintle throat area rate.	in
7062	F_{max}	Pintle motor maximum vacuum thrust.	lb
7063	P_{cmax}	Pintle motor chamber pressure at maximum vacuum thrust.	lb/in.^{2}
7064	E_{max}	Pintle motor expansion ratio at maximum vacuum thrust.	dim.
7065	A_{tmin}	Pintle motor throat area at maximum vacuum thrust.	in.^{2}
7066	C_{fmax}	Pintle motor vacuum thrust coefficient at maximum vacuum thrust.	dim.

L-No.	Symbol	Definition	Units
7067	F_{min}	Pintle motor minimum vacuum thrust.	lb
7068	P_{cmin}	Pintle motor chamber pressure at minimum vacuum thrust.	lb/in.^{2}
7069	E_{min}	Pintle motor expansion ratio at minimum vacuum thrust.	dim.
7070	A_{tmax}	Pintle motor throat area at minimum vacuum thrust.	in.^{2}
7071	C_{fmin}	Pintle motor vacuum thrust coefficient at minimum vacuum thrust.	dim.
7072	A_{amax}	Motor extinguishment throat area.	in.^{2}
7073	A_{tmn}	Pintle motor duty cycle minimum throat area.	in.^{2}
7074	A_{tmx}	Pintle motor duty cycle maximum throat area.	in.^{2}
7081	Y-CG CANARD	Lateral center-of-gravity of one canard relative to body centerline.	in.
7082	Y-CG FIN	Lateral center-of-gravity of one fin relative to body centerline.	in.
7083	X-CG CANARD	Longitudinal center-of-gravity of a set of canards.	in., BS
7084	X-CG FIN	Longitudinal center-of-gravity of a set of fins.	in., BS
7085	WT CANARD	Weight of a set of canards (a set is four).	lb
7086	WT FIN	Weight of a set of fins (a set is four).	lb
7087	CAN	Code number designating existence or nonexistence of aerodynamic canards on vehicle (0 = no canards, 1 = movable canards, 2 = fixed canards).	dim.
7088	FIN	Code number designating existence or nonexistence of aerodynamic fins on vehicle (0 = no fins, 1 = movable fins, 2 = fixed fins)	dim.
7089	I-ROLL	Roll control disturbing moment impulse.	ft-lb-sec
7090	M1	Mach number at upstream side of downstream end of last body section.	dim.

L-No.	Symbol	Definition	Units
7091	P1	Static pressure at upstream side downstream end of last body section.	psi
7092	X1	Body station of downstream end of last body section.	in., BS
7093	X0	Body station of upstream end of last body section.	in., BS
7094	SIGMA	Body surface angle relative to body centerline of last body section.	deg
7095	RMR	Roll moment arm	in.
7096	ROLL TORQUE	Maximum disturbing open roll torque.	in.-lb
7097	OFFSET TORQUE	Maximum disturbing offset roll torque.	in.-lb
7098	VORTEX TORQUE	Maximum disturbing vortex roll torque.	in.-lb
7099	AERO TORQUE	Maximum disturbing aerodynamic roll torque.	in.-lb
7100 7199	t_{Bq}	Stage time at which TVC duty points occur	sec
7200 7299	$\bar{\delta}_{Pq}$	Pitch thrust deflection angle at t_{Bq}	deg
7300 7399	$\bar{\delta}_{Yq}$	Output modified yaw thrust deflection angle at t_{Bq} for TVC design stage	deg
7400 7499	F_q	Delivered motor thrust (F) at t_{Bq} during TVC design stage	lb
7500 7599	X_{cgq}	Vehicle center-of-gravity at t_{Bq}; the TVC duty cycle point	ft
7600 7699	F_{vacq}	Vacuum motor thrust during the TVC design stage ($\bar{F}_{vac}$) at t_{Bq}	lb
7700 7799	$\dot{W}_q$	Output motor weight flow (W) at t_{Bq}	lb/sec

2. Aerodynamic Coefficients Input

L-No.	Body Input	Definition	Units
500 thru	BS_n	Body station of each corner on the vehicle outboard profile	in.
541	BD_n	Body diameter at each corner for the particular body station input	in.
		Program Accomodates 21 Separate Corners	
542	BS, Sep 1-2	Body station at which the first body separation is desired	in.
543	BS, Sep 2-3	Body station at which the second body separation is desired	in.
544	BS, Sep 3-4	Body station at which the third body separation is desired	in.
548	Ae_1	Nozzle exit area at vehicle launch	sq in.
549	Ae_2	Nozzle exit area for second burn event (program uses this in conjunction with BS, Sep 1)	sq in.
550	Ae_3	Nozzle exit area for third burn event (program uses this in conjunction with BS, Sep 2)	sq in.
551	Ae_4	Nozzle exit area for fourth burn event (program uses this in conjunction with BS, Sep 3)	sq in.
554	BD Ref	Reference body diameter. Normally is diameter of largest cylindrical body section of vehicle	sq in.
555	R_N Input Code	1. Small two stage ballistic missile 2. Large three or four stage ballistic missile 3. Large booster vehicle 4. Small air launched missile	dim.

3. Lifting Surfaces Input

L-No.	Body Input	Definition	Units
560	CANARD	Option to calculate lifting surface parameters for canards 0 No calculations made 1 Calculates and considers surface is movable 2 Calculates and considers surface is fixed	dim.
561	x_{or}	Body station of canard root chord leading edge $(x_{or} \leq x_e - c_R)$	in.
562	c_R	Canard root chord length	in.
563	ϵ_L	Complement of canard leading edge sweep angle $(24° \leqq \epsilon_L \leqq 70°)$	deg
564	λ	Canard taper ratio $(0 \leqq \lambda \leqq 0.60)$	dim.
565	τ	Canard thickness ratio $(0.030 \leq \tau \leq 0.120)$	dim.
566	x_H	Canard hinge line body station $(x_H < x_e)$	in.
567	r_b	Average body radius in distance between canard root chord leading and trailing edge	in.
568	ρ	Canard material option code 0 Aluminum 1 Steel	dim.
572	FIN	Option to calculate lifting surface parameters for fins 0 No calculations made 1 Calculates and considers surface is movable 2 Calculates and considers surface is fixed	dim.

L-No.	Body Input	Definition	Units
573	x_{or}	Body station of fin root chord leading edge ($x_{or} \leq x_e - c_R$)	in.
574	c_R	Fin root chord length	in.
575	ϵ_L	Complement of fin leading edge sweep angle ($24° \leq \epsilon_L \leq 70°$)	deg
576	λ	Fin taper ratio	dim.
577	τ	Fin thickness ratio ($0.030 \leq \tau \leq 0.120$)	dim
578	x_H	Fin hinge line body station ($x_H < x_e$)	in.
579	r_b	Average body radius in distance between fin root chord leading and trailing edge	in.
580	ρ	Fin material option code 0 Aluminum 1 Steel	dim.

Also required for lifting surface input are L-No. 554 and 555 from the aerodynamic coefficients input. Please refer to that section for a description of these two L-numbers.

4. Trajectory

For a definition of the trajectory input, please refer to Volume I, Book 1B, Section III.

5. Roll Control Requirements Input

L-No.	Symbol	Definition	Units
700	K_{tr}	Control flag where, if non-zero, the parameters $C_{N\alpha}$, $q_{\alpha m}$, and δ_{mx} are obtained from the TVC duty cycle parameters $C_{N\alpha}q$, q_{α}, max and $\bar{\delta}_{Pmax}$, respectively.	dim.
701	K_k	*Stage number.	dim.
702	D_B	*TVC duty cycle stage case diameter.	in.
703	F_{vac}	*Nominal input vacuum thrust.	lb
704	W_o	*Stage liftoff weight.	lb
705	F_{vac1}/W_{o1}	*Stage I average vacuum thrust to stage liftoff weight.	dim.
706	$C_{N\alpha}$	**Aerodynamic normal force coefficient at maximum q'_{α}.	1/deg 0.05
707	$q_{\alpha m}$	**Maximum absolute value of dynamic pressure - angle of attack product.	lb-deg/sq ft (C)
708	δ_{mx}	**Maximum thrust vector deflection angle.	deg (C)
709	ϵ_{os}	Effective offset distance.	in. (C)
710	η_{vr}	Vortex roll torque per pound of thrust factor.	in. 0.00363
711	$K_{q\alpha}$	Factor of maximum dynamic pressure - angle of attack.	dim. 1.

L-No.	Symbol	Definition	Units
712	$K_{\delta m}$	Factor of maximum thrust vector deflection angle.	dim. 1
713	K_{od}	Effective offset distance multiplier.	dim. 1
714	K_{os}	Offset roll torque multiplier.	dim. 1
715	K_{vr}	Vortex roll torque multiplier.	dim. 1
716	K'_{ar}	Aerodynamic roll torque multiplier.	dim. 1
717	M'_{rt}	Input roll torque.	in.-lb (C)
718	M'_{os}	Input offset roll torque.	in.-lb (C)
719	M'_{vr}	Input vortex roll torque.	in.-lb (C)
720	M'_{ar}	Input aerodynamic roll torque.	in.-lb (C)
721-724	B'_{qj}	Input coefficients for computing maximum dynamic pressure - angle of attack, j = 0, 1, 2, 3.	dim.
725-727	$B'_{\delta j}$	Input coefficients for computing maximum thrust vector deflection angle, j = 0, 1, 2.	dim.
728-731	$B'_{\epsilon oj}$	Input coefficient for computing effective offset distance, j = 0, 1, 2, 3.	dim.
732	η_{rc}	Ratio of roll control duty cycle to maximum roll torque - duration product.	dim.

*Set from duty cycle.
**See L700

The following is a cross reference of the L-Numbers of values that may be obtained from the duty cycle.

Roll Control L-No.	Duty Cycle L-No.
701	7027
702	7028
703	7031
704	7032
705	7029
706	7024
707	7021
708	7014

6. Aerodynamic Loading Distribution Input

The input required for aerodynamic loading distribution comes from two areas:

1. The same input required by aerodynamic coefficients. L-numbers 500 thru 555.
2. Values required from the duty cycle. L-numbers: 7021, 7022, 7024, 7025, 7027, 7052, 7053, 7057, 7058.

Please refer to the respective section for a description of the values.

B. ERROR MESSAGES

The following errors may occur in the requirements section.

Lifting Surfaces

The lifting surface taper ratio must lie between 0 and 0.6. The value was XXX.

The complement of the lifting surface leading edge sweep back angle must lie between 24 and 70 degrees. The value was XXX.

Interpolation error in setting the slope of the lifting surface linear lift coefficient. The argument was XXX.

Interpolation error in locating the lifting surface center of pressure. The argument was XXX.

Interpolation error in obtaining the Reynolds number per foot. The argument was XXX.

Interpolation error in obtaining the non-linear lift curve factor. The argument was XXX.

Interpolation error in setting up trajectory data for fins and canards. The mach number was XXX.

Normal Force Coefficients

No convergence in iteration for supersonic normal force coefficients.

Interpolation error for subsonic-transonic normal force parameter eta. The argument was XXX.

Interpolation error for subsonic-transonic normal force parameter K. The argument was XXX.

C. SAMPLE INPUT

Included in this section and the next, Sample Output, are two test cases that execute all of the Requirements Section except the trajectory portion.

INPUT SHEET

FORM TC NO. 210

NAME

DATE

PAGE

```
2      1    1    1
L500 +100 +0 +286.65 +120 +494.98 +120 +659.16 +156 +1436.85 +156
L542 +780.99 +494.98
L548 +9069.67 +13358.96 +14299.57
L554 +156 +3
L7021 +14890.846 +3516.0724
L7024 +.49272651E-1 +3.061875
L7027 +1 +156 +2.758818 5
L7031 +255581 5.4 +926416.67
L7052 +33506.929 +535.77799
L7057 +4.2350796 +0
T REQUIREMENTS TEST CASE NO. 1
```

INPUT SHEET
FORM TC NO 290

NAME | DATE | PAGE

```
 2       1
L554 +17.6 +4
L572 +1 +137.28 +22.72 +45.365 +.6 +.04 +151.669 +8.098 +0
T REQUIREMENTS TEST CASE NO. 2
```

D. SAMPLE OUTPUT

This section contains the printout of the program resulting from the input specified in the previous section, Sample Input.

CTINP INPUT

```
L500 +100 +0 +286.65 +120 +494.98 +120 +659.16 +156 +1436.85 +156
L542 +780.99 +494.98
L548 +9069.67 +13356.96 +14299.57
L554 +156 +3
L7021 +14890.846 +3516.0724
L7024 +.49272651E-1 +3.061875
L7027 +1 +156 +2.7588165
L7031 +2555815.4 +926416.67
L7052 +33506.929 +535.77799
L7057 +4.2350796 +0
1 REQUIREMENTS TEST CASE NO. 1
```

INPUT TO AERODYNAMIC COEFFICIENTS SUBROUTINE

REQUIREMENTS TEST CASE NO. 1

BODY STATION IN.	BODY DIAMETER IN.	SEP. PLANE BODY STATION IN.	STAGE EXIT AREA SQ.IN.
100.000	0.0		9065.07
286.650	120.000	780.590	13358.96
494.980	120.000	494.980	14299.57
659.160	156.000		
1436.650	156.000		

REFERENCE DIAMETER = 156.000 INCHES

REFERENCE AREA = 132.732 SQUARE FEET

OUTPUT FROM AERODYNAMIC COEFFICIENTS SUBROUTINE

REQUIREMENTS TEST CASE NO. 1

AXIAL FORCE COEFFICIENTS

INITIAL BODY

MACH NO.	TOTAL AX.FOR.COEFF.	INCR. AX. FOR. COEFF. PRESSURE	FRICTION	BASE
0.0	0.32266	0.05992	0.05255	0.21019
0.50	0.23816	0.05992	0.05135	0.12690
0.75	0.24598	0.08821	0.04820	0.10956
0.95	0.33482	0.16644	0.04594	0.12244
1.00	0.38743	0.20638	0.04547	0.13557
1.25	0.40345	0.28461	0.04291	0.07593
1.50	0.35751	0.26297	0.04041	0.05412
2.00	0.29377	0.21804	0.03580	0.03994
2.60	0.24299	0.18142	0.03110	0.03048
3.00	0.22076	0.16644	0.02857	0.02575
4.00	0.19755	0.15568	0.02426	0.01760
5.00	0.18331	0.14959	0.02138	0.01235
6.00	0.17348	0.14563	0.01944	0.00841
8.00	0.16108	0.14077	0.01689	0.00342
10.00	0.15175	0.13790	0.01386	-0.0

AFTER SEPARATION AT BODY STATION 760.990

MACH NO.	TOTAL AX.FOR.COEFF.	INCR. AX. FOR. COEFF. PRESSURE	FRICTION	BASE
1.25	0.34844	0.28461	0.02033	0.04350
1.50	0.31312	0.26297	0.01914	0.03101
2.00	0.25767	0.21804	0.01695	0.02266
2.60	0.21360	0.18142	0.01472	0.01746
3.00	0.19472	0.16644	0.01353	0.01475
4.00	0.17728	0.15568	0.01151	0.01009
5.00	0.16683	0.14959	0.01017	0.00708
6.00	0.15972	0.14563	0.00928	0.00482
8.00	0.15083	0.14077	0.00811	0.00196
10.00	0.14456	0.13790	0.00666	-0.0

OUTPUT FROM AERODYNAMIC COEFFICIENTS SUBROUTINE

REQUIREMENTS TEST CASE NO. 1

AXIAL FORCE COEFFICIENTS

AFTER SEPARATION AT BODY STATION 494.580

MACH NO.	TOTAL AX.FOR.COEFF.	INCR. AX. FOR. COEFF. PRESSURE	FRICTION	BASE
1.25	0.24137	0.25375	0.01023	-0.02260
1.50	0.22797	0.23446	0.00963	-0.01611
2.00	0.19102	0.19439	0.00852	-0.01165
2.60	0.16007	0.16174	0.00740	-0.00907
3.00	0.14753	0.14839	0.00680	-0.00766
4.00	0.14031	0.13976	0.00580	-0.00524
5.00	0.13632	0.13486	0.00513	-0.00366
6.00	0.13387	0.13168	0.00469	-0.00250
8.00	0.13089	0.12779	0.00412	-0.00102
10.00	0.12887	0.12548	0.00339	-0.0

OUTPUT FROM AERODYNAMIC COEFFICIENTS SUBROUTINE

REQUIREMENTS TEST CASE NO. 1

NORMAL FORCE COEFFICIENT

INITIAL BODY

MACH NO.	CN ALPHA PER DEG.	XCP IN.	CN ALPHA*XCP PER DEG. IN.
0.0	0.03616	431.740	15.611
0.50	0.03770	457.790	17.259
0.75	0.04009	465.743	19.472
0.95	0.04264	538.098	22.947
1.00	0.04367	557.915	24.366
1.25	0.04070	437.750	17.817
1.50	0.03952	412.193	16.285
2.00	0.03959	385.034	15.242
2.60	0.06972	563.044	39.255
3.00	0.07140	582.654	41.603
4.00	0.07109	609.295	43.312
5.00	0.06696	612.725	41.028
6.00	0.06368	614.360	39.125
8.00	0.05463	581.710	31.776
10.00	0.04885	551.856	26.961

AFTER SEPARATION AT BODY STATION 780.990

MACH NO.	CN ALPHA PER DEG.	XCP IN.	CN ALPHA*XCP PER DEG. IN.
1.25	0.03519	372.511	13.124
1.50	0.03438	369.280	12.696
2.00	0.03485	358.281	12.486
2.60	0.05222	429.480	22.428
3.00	0.05182	427.806	22.170
4.00	0.04935	417.410	20.598
5.00	0.04603	404.475	18.617
6.00	0.04340	394.217	17.109
8.00	0.03885	373.560	14.513
10.00	0.03612	359.391	12.980

OUTPUT FROM AERODYNAMIC COEFFICIENTS SUBROUTINE

REQUIREMENTS TEST CASE NO. 1

NORMAL FORCE COEFFICIENT

AFTER SEPARATION AT BODY STATION 494.980

MACH NO.	CN ALPHA PER DEG.	XCP IN.	CN ALPHA*XCP PER DEG. IN.
1.25	0.02027	229.757	4.657
1.50	0.01983	227.763	4.516
2.00	0.02014	222.177	4.475
2.60	0.02944	290.678	8.703
3.00	0.03005	290.753	8.747
4.00	0.03033	290.581	8.814
5.00	0.02996	288.509	8.649
6.00	0.02951	286.180	8.445
8.00	0.02833	280.840	7.956
10.00	0.02743	276.352	7.609

REQUIREMENTS TEST CASE NO. 1

ROLL CONTROL REQUIREMENTS

INPUT

MANDATORY

STG	CASE TIA	STG VAC THRUST	STG LIFTOFF WT	REF VAC THR/WT
1	156.0000	0.25550150E 07	0.92641665E 06	2.750019

OPTIONAL

OFFSET TCR MULT	VORTEX TCR MULT	AERO TCR MULT
1.00000	1.00000	1.00000
OFFSET MULT	MAX DELTA MULT	Q-ALPHA MULT
1.00000	1.00000	1.00000
VORTEX COEF	AERO NORM COEF	
0.00363	0.05000	

OUTPUT

ROLL TORQUE	OFFSET TORQUE	VORTEX TORQUE	AERO TORQUE
0.19716763E 06	0.14862494E 06	0.92776055E 04	0.12922700E 06
MAX DELTA	OFFSET	MAX Q-ALPHA	
2.92610	1.1387	17100.59	

OUTPUT FROM AERODYNAMIC COEFFICIENTS SUBROUTINE

BODY NORMAL FORCE LOADING DISTRIBUTION

FLIGHT PARAMETERS

MACH NO.	ALTITUDE FT.	PITCH ANGLE DEG.	YAW ANGLE DEG.	RESULT. ANGLE DEG.
3.06	33566.9	4.24	0.0	4.24

DYN. PRESS. PSF.	Q*ALPHAPR PSF.-DEG.	RESULT. FORCE LB.	FORCE ANG. DEG.	XCP IN.,B.S.
3516.1	14690.8	97387.13	0.0	585.30

LOADING DISTRIBUTION

	BODY STATION IN.	LOAD LB./IN.	BODY STATION IN.	LOAD LB./IN.	BODY STATION IN.	LOAD LB./IN.
1	100.00	0.0	137.33	75.47	174.66	150.94
	211.99	226.41	249.32	301.88	286.65	377.34
2	286.65	41.77	328.32	40.00	369.98	36.26
	411.65	36.61	453.31	34.96	494.98	33.39
3	494.98	165.45	527.82	175.06	560.65	184.64
	593.49	194.18	626.32	203.70	659.16	215.18
4	659.16	25.97	814.70	19.43	970.24	14.07
	1125.77	9.67	1281.31	6.06	1436.85	3.10

```
CTINP INPUT

    L554 +17.6 +4
    L572 +1 +137.28 +22.72 +45.365 +.6 +.04 +151.665 +6.098 +0
    T REQUIREMENTS TEST CASE NO. 2
```

INPUT TO LIFTING SURFACES SUBRCUTINE

REQUIREMENTS TEST CASE NO. 2

FINS

ROOT CHORD L.E. IN. BODY STA.	ROOT CHORD LENGTH IN.	THICKNESS RATIC DIM.
137.2800	22.7200	0.04CC
COMPL. OF SWEEP ANGLE DEG.	**TAPER RATIO DIM.**	**HINGE LINE IN. BODY STA.**
45.3650	0.6000	151.6650
BODY RADIUS IN.	**REFERENCE DIAMETER IN.**	**MATERIAL**
8.0980	17.6000	ALUPINUP

OUTPUT FROM LIFTING SURFACES SUBROUTINE

REQUIREMENTS TEST CASE NO. 2

FINS

ASPECT RATIO DIM.	PLANFORM AREA/PAIR SQ. FEET	PLANFORM SEMI SPAN IN.
1.013	2.324	9.2045

MEAN AERO. CHORD IN.	MAC L.E. LOC. IN. BODY STA.	MAC SPAN LOC. IN.
16.5547	141.4453	4.2167

HINGE LINE LOC. IN. BODY STA.	WEIGHT/SET LBS.	MATERIAL
151.6690	25.082 *	ALUMINUM
	71.025	STEEL

CENTER OF GRAVITY IN. X	CENTER OF GRAVITY IN. Y,Z	PLANFORM CENTROID IN. X	PLANFORM CENTROID IN. Y,Z
150.2742	11.4084	150.7227	4.2167

NON-LIN. LIFT FACTOR 1/DEG. SQ.	CENTER OF PRESSURE (Y,Z) IN.	REF. AREA SQ.FT.
0.000659	12.0045	1.669

MACH NO.	MIN. DRAG COEFF. DIM.	PRESS. DRAG COEFF. DIM.	FRICTION DRAG COEFF. DIM.	DRAG DUE TO LIFT FACTOR RAD.
0.0	0.01117	0.0	0.01006	0.49223
0.50	0.01260	0.0	0.00983	0.46324
0.75	0.01498	0.0	0.00893	0.47223
0.95	0.02965	0.0	0.00834	0.46057
1.00	0.03126	0.02305	0.00820	0.45725
1.25	0.02754	0.01997	0.00757	0.36866
1.50	0.02459	0.01759	0.00700	0.36999
2.00	0.02016	0.01419	0.00599	0.43153
2.60	0.01649	0.01149	0.00500	0.50931
3.00	0.01464	0.01018	0.00446	0.56022
4.00	0.01134	0.00791	0.00342	0.70605
5.00	0.00917	0.00646	0.00272	0.89050
6.00	0.00766	0.00544	0.00222	1.07557
8.00	0.00571	0.00413	0.00158	1.44277
10.00	0.00453	0.00332	0.00121	1.80061

* MATERIAL SPECIFIED

OUTPUT FROM LIFTING SURFACES SUBROUTINE

REQUIREMENTS TEST CASE NO. 2

FINS

MACH NO.	LIFT COEFF. SLOPE 1/DEG.	CENTER OF PRESSURE IN. BODY STA.
0.0	0.03546	147.9394
0.50	0.03612	148.2693
0.75	0.03696	149.7224
0.95	0.03790	149.4766
1.00	0.03817	150.7226
1.25	0.04734	150.7226
1.50	0.04717	150.7226
2.00	0.04045	150.7226
2.60	0.03427	150.7226
3.00	0.03115	150.7226
4.00	0.02472	150.7226
5.00	0.01960	150.7226
6.00	0.01623	150.7226
8.00	0.01210	150.7226
10.00	0.00965	150.7226

FINS

REF. AREA (PLANFORM AREA/PAIR) SQ. FT.

2.324

HINGE LINE DIM.

0.63332

MACH NO.	MIN. DRAG COEFF. DIM.	DRAG DUE TO LIFT FACTOR RAD.	LIFT COEFF. SLOPE 1/DEG.	CENTER OF PRESSURE DIM.
0.0	0.00812	0.67699	0.02578	0.46917
0.50	0.00916	0.66462	0.02626	0.48368
0.75	0.01085	0.64948	0.02687	0.50363
0.95	0.02156	0.63344	0.02755	0.54563
1.00	0.02273	0.62888	0.02775	0.59167
1.25	0.02002	0.50704	0.03442	0.59167
1.50	0.01786	0.50887	0.03430	0.59167
2.00	0.01467	0.59351	0.02941	0.59167
2.60	0.01195	0.70047	0.02492	0.59167
3.00	0.01065	0.77050	0.02265	0.59167
4.00	0.00824	0.97107	0.01797	0.59167
5.00	0.00667	1.22474	0.01425	0.59167
6.00	0.00557	1.47902	0.01160	0.59167
8.00	0.00415	1.98431	0.00880	0.59167
10.00	0.00329	2.48747	0.00702	0.59167

SECTION IV

HARDWARE

A. INPUT

1. DUTY CYCLE INPUT

Duty cycle data required for the Hardware Section may be obtained three ways:

1. By executing the trajectory simulation portion of the program.
2. Supplying the duty cycle input with the Requirements Section input.
3. Supplying the duty cycle input with the Hardware Section input.

For a description of the duty cycle input please refer to the duty cycle input discussion in Section III.A.1.

The input data for the hardware subroutines are divided into two types, routine input and optional input. Routine data are those which usually are input for each computer run unless stored values are desired. Optional data are those whose values are relatively constant. Typical of the optional data are the empirical constants used in some of the equations; density; strength levels; and moduli of materials used and data input in tabular form, such as the tables defining weights of some of the components. A nominal value for each piece of optional data is stored in the program; the nominal value will be used unless a new value for the parameter is read in from cards. Once a parameter is changed by card for a case, it will remain at the changed

value until again changed or until the user specifies by control card input that the values are to be reset to their initial default values.

This concept of optional data permits running the program with minimum input data for most applications, and yet permits easily changing the optional data should the requirements of a specific case require. The routine and optional input for each of the hardware design subroutines is listed in the tables that follow.

2. NOZZLE INPUT

a. Nozzle Routine Input

L-No.	Symbol	Definition	Value	Fortran Symbol
0	TPNOZ	Nozzle type =1, submerged fixed =2, subsonic splitline =3, external fixed =4, hinged =5, integral =6, submerged inlet, supersonic splitline =7, external inlet, supersonic splitline	--	TPNOZ
1	CONTRL	Thrust vector control =0, no nozzle TVC =1, liquid injection =2, hot gas =3, jet tabs =4, gimbal ring =5, ball and socket =6, flexible seal	--	CONTRL
2	PCLOC	Pivot center location control, 4 or 5 control, 6 =1, at seal =2, forward of seal =3, aft of seal	 1 2	PCLOC

L-No.	Symbol	Definition	Value	Fortran Symbol
3	HGVMT	Hot gas valve mounting =1, nozzle mounted submerged pintle valve =2, closure mounted submerged pintle valve =3, plenum mounted submerged pintle valve =4, external pintle valve =5, external jet pipe valve =6, external rotating valve	4	HGVMT
4	TPT	Throat code =1, tungsten =2, graphite =3, plastic =4, actively cooled	3	TPT
5	TPGEO	Exit configuration =1, conical exit =2, contour exit	1	TPGEO
6	TPCSE	Case material =1, metal =2, filament wound glass	1	TPCSE
7	TPBND	Binder type =1, PBAA or PBAN =2, CTPB	1	TPBND

Only one of the following four parameters needs to be input.

L-No.	Symbol	Definition	Value	Fortran Symbol
10	DTAVG	Average throat diameter	0 in.→	DIATAV
11*	AT	Average throat area	0 sq in.→	AT
12	DTINT	Initial throat diameter	0 in.→	DIATO
13	ATINT	Initial throat area	0 sq in.→	ATO

*Nonzero input in these locations overrides data from duty cycle. The data are not required if duty cycle values are to be used.

For a conical exit cone, input two of the following: THETAI, LNZ, or EPS (EPS can be either initial expansion ratio, EPSINT, or average expansion ratio, EPSAVG).

For a contoured exit cone, input three of the following: THETAI, DELTH, LNZ, or EPS (EPS is same as defined in the preceding sentence).

L-No.	Symbol	Definition	Value	Fortran Symbol
14	THETAI	Initial angle of contour or half angle of cone		THETAI
		Conical	15 deg	
		Contour	23 deg	
15	DELTH	THETAI minus angle at exit plane (turnback angle)	10 deg	DELTH
16	LNZ	Length, throat to exit	0 in.	ELNZ
17	EPSINT	Initial expansion ratio	0	EPSO
18*	EPSAVG	Average expansion ratio	0	EPSAV
19*	TA	Time of motor operation	0 sec	TA
20*	PC	Average chamber pressure	0 psi	PC
22*	BD	Case diameter	0 in.	DIACSE
23*	XNF	Motor station of nozzle flange face	0 ft	ELXNF

These values are input only if a two level, motor operation is required.

L-No.	Symbol	Definition	Value	Fortran Symbol
51	BTA	Boost action time	0 sec	BTA
52	BPCA	Boost phase operating pressure	0 psi	BPCA
53	BXDOT	Boost phase throat erosion rate	0 mils/sec	BXDOT
54	CTA	Coast time (motor shutdown)	0 sec	CTA

*Nonzero input in these locations overrides data from duty cycle. The data are not required if duty cycle values are to be used.

b. Nozzle Optional Input

L-No.	Symbol	Definition	Value	Fortran Symbol
21	DELMXI	Design thrust vector angle	max. of 3°, δ_{pmax}, δ_{ymax}	DELMXI

If a nonzero value is input, that value is used. If DELMXI = O, D-DESIGN is used if nonzero; otherwise, the maximum of δ_{pmax} and δ_{ymax} is used. If all four are zero, three degrees are used. (For TYPNOZ = 4, DELMXI is replaced by twice DELMXI.)

L-No.	Symbol	Definition	Value	Fortran Symbol
24	ERATIO	Injection port location, EPS/ EPSINT (nozzle types 1 and 3)	0	ERATIO
25	XIRAT	Injection port location, X/LNZ (nozzle types 1 and 3)	0.5	XIRAT
26	XFRAT	Flange location, X/LNZ (nozzle types 1, 5, and 6)	0.3	XFRAT
27	MEOP	Structural design pressure	(C)* psi	POMAXE

If not input, 1.1 x PC-MAX is used if nonzero. If PC-MAX = O, 1.2 x PC is used.

L-No.	Symbol	Definition	Value	Fortran Symbol
28	PA	Ambient pressure	0.0 psi	PA
29	RRATD	Downstream external radius ratio	0.6	RRATD
30	DIABT	Diameter at station 4up (nozzle types 2 and 4)	(C) in.	DIABT
31	THETAC	Inlet angle		THETAC
		(nozzle types 2, 3, and 7)	45 deg	
		(nozzle type 4)	3.5 deg	
		(nozzle type 4 with pintle nozzle)	45 deg	
32	RNOZB2	Radius to inside of flange	(C) in.	RNOZB2
33	FEJDES	Design nozzle ejection load	(C) lb	FEJDES

*C indicates that if value is not input, it will be calculated in the program.

L-No.	Symbol	Definition	Value	Fortran Symbol
34	TEC	Chamber temperature	6,260°R	TEC
		Pintle nozzle	6,020°R	
35**	GAM	Isentropic exponent of exhaust gases	1.18	GAM
		Pintle nozzle	1.147	
36**	CSTAR	Characteristic velocity	5,200 ft/sec	CSTAR
		Pintle nozzle	5,120 ft/sec	
37	ALUM	Propellant aluminum content	16%	ALUM
		Pintle nozzle	12%	
38	BINDER	Propellant binder content	14%	BINDER
		Pintle nozzle	18%	
39	BLOWCO	Blowing coefficient	(C)*%	BLOWCO

c. Nozzle Optional Input for Cooled Throat

L-No.	Symbol	Definition	Value	Fortran Symbol
56	TWIN	Thickness of porous insert	(C) in.	TWIN
57	TPINS	Allowable throat insert temperature	4,000° F	TPINS
58	TMAN	Manifold coolant temperature	140° F	TMAN
59	PRNDTL	Prandtl number of exhaust gas	0.7[illegible]	PRNDTL
60	VISGAS	Viscosity of exhaust gas	6×10^{-5} lb/ft-sec	VISGAS
61	VISXP	Viscosity exponent of exhaust gas	0.6	VISXP
62	XMWG	Molecular weight of exhaust gas	26	XMWG

*C indicates that if value is not input, it will be calculated in the program.
**The stored value will be used if no value is available from the duty cycle.

L-No.	Symbol	Definition	Value	Fortran Symbol
63	CPCOOL	Specific heat of coolant	0.523 Btu/lb° F	CPCOOL
64	ACCOOL	Porous insert flow constant	0.0593	ACCOOL
65	BCOOL	Porous insert flow constant	15.08	BCOOL
66	XMWC	Molecular weight of coolant	17	XMWC
67	HVAP	Coolant heat of vaporization (use 0 if not liquid at manifold)	509 Btu/lb	HVAP
68	CTMC	Coolant tank material code	1	CTMC
69	TSC	Coolant tank shape code =1, toroidal =2, spherical	(C)*	TSC
70	RHOCL	Density of coolant	0.0215 lb/cu in.	RHOCL

d. Nozzle Optional Input for Movable Nozzle

L-No.	Symbol	Definition	Value	Fortran Symbol
71	RMXB	Radial limit line	(C) in.	RMXB
72	XIM	Axial limit line	(C) in.	XIM
73	ANGN	Iteration start angle	(C) deg	ANGN
74	ANGM	Iteration limit angle	(C) deg	ANGM
75	ELMS	Minimum seal gap length Flexible seal Others	 0.3 in. (C) in.	ELMS
76	DALL	Iteration closure angle	0.003 deg	DALL

*C indicates that if value is not input, it will be calculated in the program.

L-No.	Symbol	Definition	Value	Fortran Symbol
77	DANN	Iteration step angle	3 deg	DANN
78	TFL	Radial nose thickness	(C)* in.	TFL
79	OFLG	Matching flag	1	OFLG

e. Nozzle Optional Input for Ball Seal

L-No.	Symbol	Definition	Value	Fortran Symbol
81	PSIL	Allowable liner pressure load supersonic splitline (Applies only if CONTRL = 5)	5,000 psi	PSIL
82	CAMP	Amplification factor	(C)	CAMP
83	AMPFLG	Amplification factor flag =0, do not modify DELMXI =1, modify DELMXI by CAMP (Applies only to TYPNOZ = 6 or 7)	0	AMPFLG

f. Nozzle Optional Input for Gimbal Ring

L-No.	Symbol	Definition	Value	Fortran Symbol
85	HGR	Height of section (radial)	(C) in.	HGR
86	HRR	Ratio of height to ID		HRR
		subsonic splitline or integral	0.15	
		supersonic splitline	0.08	
87	RBH	Ratio of width to height		RBH
		subsonic or supersonic splitline	2	
		integral	2	
88	RWB	Ratio of wall thickness to width		RWB
		subsonic splitline or integral	0.25	
		supersonic splitline	0.5	

*C indicates that if value is not input, it will be calculated in the program.

L-No.	Symbol	Definition	Value	Fortran Symbol
89	RWH	Ratio of wall thickness to height		RWH
		subsonic splitline or integral	0.15	
		supersonic splitline	0.5	
90	DLAX	Allowable axial deflection	(C)* in.	DLAX
91	DLLAT	Allowable lateral deflection	0.01 in.	DLLAT

g. Nozzle Optional Input for Flexible Seal

L-No.	Symbol	Definition	Value	Fortran Symbol
94	HGT	Height of seal	(C) in.	HGT
95	BETA1	Inner seal angle	45 deg	BETA1
96	BETA2	Outer seal angle	55 deg	BETA2
97	SHANG	Shear angle	10 deg	SHANG
98	TMTR	Ratio of metal to rubber	2	TMTR
99	TM	Thickness of metal shim	0.05 in.	TM
100	RHT	Ratio of height to chord	1	RHT
101	FSB	Shim stress factor of safety	1.25	FSB
102	FSH	Rubber shear factor of safety	1.25	FSH
103	EMSLIN	Thickness of insulated splitline structure	(C) in.	EMSLIN
104	BTK	Boot thickness	0.2 in.	BTK

*C indicates that if value is not input, it will be calculated in the program.

h. Nozzle Optional Input for Throat Insert

L-No.	Symbol	Definition	Value	Fortran Symbol
105	TVOID	Plenum height, cooled throat	(C)* in.	TVOID
106	TTIV	Virgin insert thickness at end of firing	(C) in.	TTIV
107	TTIE	Thickness of insert erosion	(C) in.	TTIE

i. Exit Ring Optional Input

L-No.	Symbol	Definition	Value	Fortran Symbol
108	XACT	X distance from throat to point of actuator attachment	(C) in.	XACT
109	RACT	R distance from throat to point of actuator attachment	(C) in.	RACT

j. Nozzle Optional Input for Pintle Nozzle

L-No.	Symbol	Definition	Value	Fortran Symbol
40	PNOZ	Control = 1, design pintle nozzle	0	PNOZ
41	PTYPE	Pintle type = 1, solid tungsten = 2, tungsten shell = 3, ablative sleeve	(C)	PTYPE
42	FMAX	Maximum thrust level	(C)	FMAX
43	PCMAX	Chamber pressure at FMAX	(C)	PCMAX
44	EPSMAX	Expansion ratio at FMAX	(C)	EPSMAX
45	ATMINA	Aerodynamic throat area at FMAX	(C)	ATMINA

*C indicates that if value is not input, it will be calculated in the program.

L-No.	Symbol	Definition	Value	Fortran Symbol
46	FMIN	Minimum nonzero thrust level	(C)*	FMIN
47	PCMIN	Chamber pressure at FMIN	(C)	PCMIN
48	EPSMIN	Expansion ratio at FMIN	(C)	EPSMIN
49	ATMAXA	Aerodynamic throat area at FMIN	(C)	ATMAXA
50	ATEXTA	Aerodynamic throat area required for motor extinguishment	(C)	ATEXTA
55	EXT	Control = 0, do not design for motor extinguishment = 1, design for motor extinguishment	0	EXT
80	GTYPE	Grain type = 1, constant surface area = 2, variable surface area	2	GTYPE
92	ATMXA	Maximum aerodynamic throat area	(C)	ATMXA
93	ATMNA	Minimum aerodynamic throat area	(C)	ATMNA
1068	RPTIP	Pintle tip radius	(C)	RPTIP
1069	TB	Total burn time	(C)	TB
1070	NSTT	Number of struts	3	XNSTT
1071	BETAST	Strut angle	(C)	BETAST
1072	PHYD	Hydraulic supply pressure	3,000	PHYD
1073	LLVDT	Length of feedback (LVDT)	1.75	XLLVDT

*C indicates that if value is not input, it will be calculated in the program.

L-No.	Symbol	Definition	Value	Fortran Symbol
1074	ODLVDT	Outside diameter of feedback (LVDT)	0.5	ODLVDT
1075	ABAL	Percent of pintle tip which is area balanced	(C)*	ABAL
1076	BREXP	Propellant burn rate exponent	0.75	BREXP
1077	CDB	Boost discharge coefficient	0.97	CDB
1078	CDS	Sustain discharge coefficient	0.87	CDS
1079	CDEXT	Extinguishment discharge coefficient	0.85	CDEXT
1080	BXDOTP	Pintle erosion rate during boost conditions	(C)	BXDOTP
1081	SXDOTP	Pintle erosion rate during sustain conditions	(C)	SXDOTP
1082	ODP	Outside diameter of pintle	(C)	ODP
1083	STR	Maximum pintle stroke	(C)	STR
1084	STRDOT	Pintle velocity	(C)	STRDOT
1085	INTMC	Integral of STRDOT	(C)	XINTMC
1086	LPNT	Total pintle length	(C)	XLPNT
1087	RIDSRT	Radius to inside diameter of pintle insert	(C)	RIDSRT
1088	L1200	Axial length from pintle tip to 1,200°F isotherm	(C)	XL1200

*C indicates that if value is not input, it will be calculated in the program.

k. Nozzle Optional Input Equation Constants

L-No.	Symbol	Value	L-No.	Symbol	Value
2090	CN1	0.1	2131	CN42	-0.377863×10^{-1}
2091	CN2	-0.920935	2132	CN43	0.232029×10^{-2}
2092	CN3	-0.142653×10^{-1}	2133	CN44	-0.313475×10^{-1}
2093	CN4	-0.103953×10^{-3}	2134	CN45	-0.242349
2094	CN5	0.277405×10^{-5}	2135	CN46	-0.445288×10^{-2}
2095	CN6	0.139939×10^{-1}	2136	CN47	-0.370606×10^{-1}
2096	CN7	0.503518×10^{-4}	2137	CN48	-0.218255×10^{-1}
2097	CN8	0.108327	2138	CN49	0.26454×10^{-2}
2098	CN9	-0.106016×10^{1}	2139	CN50	0.39659
2099	CN10	-0.793869×10^{-2}	2140	CN51	0.1[illegible]452 x 10^{1}
2100	CN11	-0.312109×10^{-3}	2141	CN52	-0.618151
2101	CN12	0.568657×10^{-5}	2142	CN53	0.600477×10^{-2}
2102	CN13	0.149991×10^{-1}	2143	CN54	-0.184792×10^{-3}
2103	CN14	0.363106×10^{-4}	2144	CN55	-0.585812×10^{-1}
2104	CN15	0.137701×10^{1}	2145	CN56	0.117637
2105	CN16	0.492648×10^{1}	2146	CN57	-0.8485
2106	CN17	0.146663×10^{2}	2147	CN58	-1.0435
2107	CN18	-0.437538	2148	CN59	5
2108	CN19	0.149242×10^{1}	2149	CN60	0.42
2109	CN20	-0.212665	2150	CN61	1
2110	CN21	0.160043×10^{-1}	2151	CN62	0.4
2111	CN22	-0.112126×10^{2}	2152	CN63	0.0131
2112	CN23	0.192557×10^{2}	2153	CN64	1
2113	CN24	-0.135053×10^{2}	2154	CN65	0.5
2114	CN25	-0.108109×10^{1}	2155	CN66	0.092
2115	CN26	0.226633×10^{-1}	2156	CN67	0.031
2116	CN27	0.13059	2157	CN68	-0.00022
2117	CN28	-0.16851×10^{2}	2158	CN69	0.00528
2118	CN29	-0.246747×10^{2}	2159	CN70	0.1
2119	CN30	0.20848×10^{2}	2160	CN71	1
2120	CN31	0.290881	2161	CN72	0
2121	CN32	-0.328595×10^{-1}	2162	CN73	0.5
2122	CN33	-0.386683	2163	CN74	1
2123	CN34	0.715927	2164	CN75	0
2124	CN35	0.1	2165	CN76	-0.00042
2125	CN36	0.5	2166	CN77	0.00361
2126	CN37	0.130089×10^{1}	2167	CN78	0.000069
2127	CN38	0.637875×10^{-1}	2168	CN79	-0.00011
2128	CN39	0.281842×10^{-1}	2169	CN80	0.00158
2129	CN40	-0.209463×10^{1}	2170	CN81	0.1875
2130	CN41	0.272717	2171	CN82	0

L-No.	Symbol	Value	L-No.	Symbol	Value
2172	CN83	0	2215	CN126	0.033
2173	CN84	0	2216	CN127	1.908×10^{5}
2174	CN85	0	2217	CN128	7.84
2175	CN86	1.661771×10^{-1}	2218	CN129	1.0183
2176	CN87	1.026857×10^{-2}	2219	CN130	-0.0183
2177	CN88	-2.727812×10^{-5}	2220	CN131	0.95
2178	CN89	3.204651×10^{-8}	2221	CN132	20
2179	CN90	$-1.341017 \times 10^{-11}$	2222	CN133	15
2180	CN91	1.287107×10^{-1}	2223	CN134	0.693
2181	CN92	7.624351×10^{-3}	2224	CN135	-0.0123
2182	CN93	-1.914588×10^{-5}	2225	CN136	0.25
2183	CN94	2.179663×10^{-8}	2226	CN137	0.02
2184	CN95	$-8.891198 \times 10^{-12}$	2227	CN138	0.75
2185	CN96	1.094957×10^{-1}	2228	CN139	0.047
2186	CN97	6.237939×10^{-3}	2229	CN140	0.1
2187	CN98	-1.715526×10^{-5}	2230	CN141	5
2188	CN99	1.980992×10^{-8}	2231	CN142	1.7
2189	CN100	$-8.062882 \times 10^{-12}$	2232	CN143	-0.01
2190	CN101	0.036	2233	CN144	7
2191	CN102	0.68	2234	CN145	1.215
2192	CN103	-66.5	2235	CN146	-1.065
2193	CN104	0.02	2236	CN147	0.3333
2194	CN105	0.68	2237	CN148	1.125
2195	CN106	-90.4	2238	CN149	1.02
2196	CN107	0	2239	CN150	0.[illegible]9
2197	CN108	1	2240	CN151	[illegible].234
2198	CN109	0	2241	CN152	1.856
2199	CN110	2	2242	CN153	1
2200	CN111	4.2	2243	CN154	0.3
2201	CN112	1	2244	CN155	1.05
2202	CN113	1.25	2245	CN156	300
2203	CN114	0.4	2246	CN157	0.84
2204	CN115	0.16	2247	CN158	100,000
2205	CN116	5	2248	CN159	4
2206	CN117	0.41	2249	CN160	1.5
2207	CN118	1.12	2250	CN161	1.5
2208	CN119	0.6	2251	CN162	1.1
2209	CN120	8.6	2252	CN163	90
2210	CN121	0.593	2253	CN164	70
2211	CN122	0.008	2254	CN165	20
2212	CN123	0.28	2255	CN166	30
2213	CN124	250	2256	CN167	0.2
2214	CN125	1.79×10^{-5}	2257	CN168	0.2

L-No.	Symbol	Value
2258	CN169	0.1
2259	CN170	10,000
2260	CN171	500
2261	CN172	0.088
2262	CN173	0.28
2263	CN174	0.9
2264	CN175	0.5
2265	CN176	1.05
2266	CN177	0.2
2267	CN178	0.01
2268	CN179	1.706
2269	CN180	0.566
2270	CN181	0.05
2271	CN182	0.01
2272	CN183	3
2273	CN184	1
2274	CN185	0.975
2275	CN186	0.5
2276	CN187	0.975
2277	CN188	0.0154
2278	CN189	0.1
2279	CN190	1.4517
2280	CN191	0.4
2281	CN192	0.92
2282	CN193	0.8
2283	CN194	275
2284	CN195	1.2×10^{12}
2285	CN196	74,375
2286	CN197	6×10^{5}
2287	CN198	0.0015
2288	CN199	0.01
2289	CN200	4×10^{5}
2290	CN201	0.01
2291	CN202	1,000
2292	CN203	0.043
2293	CN204	205.67
2294	CN205	2
2295	CN206	5
2296	CN207	8
2297	CN208	2
2298	CN209	0.67
2299	CN210	1
2300	CN211	0.02
2301	CN212	1
2302	CN213	10
2303	CN214	0
2304	CN215	1
2305	CN216	0.00316
2306	CN217	0.000691
2307	CN218	1.75
2308	CN219	2
2309	CN220	0.75
2310	CN221	1
2311	CN222	1.25
2312	CN223	4
2313	CN224	60
2314	CN225	1.724573
2315	CN226	-2.71846×10^{-1}
2316	CN227	-8.502382
2317	CN228	1.577494×10^{1}
2318	CN229	-1.170823
2319	CN230	7.241182×10^{-1}
2320	CN231	-1.063764
2321	CN232	4.063785×10^{-1}
2322	CN233	-7.466649×10^{-2}
2323	CN234	6.190602×10^{-1}
2324	CN235	-8.186164×10^{-2}
2325	CN236	3.528282×10^{-3}
2326	CN237	1
2327	CN238	1
2328	CN239	8,950
2329	CN240	-7,200
2330	CN241	0.125
2331	CN242	30
2332	CN243	0.2
2333	CN244	0.001
2334	CN245	0.01
2335	CN246	0.1
2336	CN247	5
2337	CN248	0.025
2338	CN249	0.000556
2339	CN250	5
2340	CN251	0.02
2341	CN252	0.6

L-No.	Symbol	Value	L-No.	Symbol	Value
2342	CN253	0.04	2385	CN296	1.8831
2343	CN254	1	2386	CN297	20.17
2344	CN255	1.2	2387	CN298	1.03
2345	CN256	0	2388	CN299	0.25
2346	CN257	0.01	2389	CN300	2.0045×10^{-4}
2347	CN258	0.043	2390	CN301	0.3
2348	CN259	0.3183	2391	CN302	0
2349	CN260	1.15	2392	CN303	0.2
2350	CN261	1.5	2393	CN304	0.1
2351	CN262	-0.6	2394	CN305	4.8967×10^{-2}
2352	CN263	-1.5	2395	CN306	-5.0377×10^{-4}
2353	CN264	1.3	2396	CN307	3.8376×10^{-4}
2354	CN265	0.01	2397	CN308	-3.2252×10^{-6}
2355	CN266	120	2398	CN309	7.3018×10^{-8}
2356	CN267	50	2399	CN310	8.810122×10^{-1}
2357	CN268	7.47437×10^{-1}	2400	CN311	-6.936014×10^{-2}
2358	CN269	-1.269336×10^{-2}	2401	CN312	1.055942×10^{-3}
2359	CN270	7.382576×10^{-4}	2402	CN313	-5.584052×10^{-6}
2360	CN271	2.161375×10^{-6}	2403	CN314	$-8.871268 \times 10^{-10}$
2361	CN272	1.043734×10^{-7}	2404	CN315	1.151603
2362	CN273	$-8.674603 \times 10^{-10}$	2405	CN316	6.403822×10^{-2}
2363	CN274	1.09376×10^{-7}	2406	CN317	3.581672×10^{-4}
2364	CN275	0.0125	2407	CN318	-6.030332×10^{-6}
2365	CN276	19.6255	2408	CN319	1.1733×10^{-7}
2366	CN277	46.04	2409	CN320	0.48
2367	CN278	-17.306	2410	CN321	3
2368	CN279	0.3	2411	CN322	9297.32
2369	CN280	50.95	2412	CN323	302.49
2370	CN281	-100	2413	CN324	-0.329389
2371	CN282	[illegible]	2414	CN325	-9516.2
2372	CN283	1.0144	2415	CN326	-0.02809
2373	CN284	0.1193	2416	CN327	-213.2
2374	CN285	1.005	2417	CN328	-19.6033
2375	CN286	1.66336	2418	CN329	9.80201
2376	CN287	74.4496	2419	CN330	1963.565
2377	CN288	-8.65985	2420	CN331	229.3648
2378	CN289	1.1	2421	CN332	-0.8
2379	CN290	1.3	2422	CN333	-2013.7783
2380	CN291	0.5	2423	CN334	-0.05005
2381	CN292	1	2424	CN335	-75.06177
2382	CN293	0	2425	CN336	0
2383	CN294	0.1	2426	CN337	0
2384	CN295	4,512	2427	CN338	0.25

L-No.	Symbol	Value	L-No.	Symbol	Value
2428	CN339	1	1589	CN382	-2.9438
2429	CN340	1	1590	CN383	1.4565
2430	CN341	1	1591	CN384	1.0151
2431	CN342	1	1592	CN385	6.0781
2432	CN343	0.417	1593	CN386	-4.9078
2433	CN344	0.25	1594	CN387	30
2434	CN345	0.204	1595	CN388	0.45
2435	CN346	1	1596	CN389	0.6
2436	CN347	1	1597	CN390	20
2437	CN348	0.3	1598	CN391	0.01
2438	CN349	0.333	1599	CN392	0.1872
2439	CN350	0.25	1600	CN393	0.941
2440	CN351	0.3	1601	CN394	0.0227
2441	CN352	1	1602	CN395	0.1810
2442	CN353	0.3	1603	CN396	0.028
2443	CN354	0.5	1604	CN397	0.5
2444	CN355	0.333	1605	CN398	0.35
2445	CN356	0.333	1606	CN399	0.441
2446	CN357	0.25	1607	CN400	49,500
2447	CN358	0.4	1608	CN401	-228,300
2448	CN359	0.8124	1609	CN402	0.007
2449	CN360	0.0124	1610	CN403	0.1
1568	CN361	0.06	1611	CN404	0.347
1569	CN362	0.1	1612	CN405	0.8
1570	CN363	1.5	1613	CN406	0.5
1571	CN364	1	1614	CN407	4
1572	CN365	100	1615	CN408	0.01
1573	CN366	-1.54631×10^6	1616	CN409	1.0
1574	CN367	-7.10048×10^2	1617	CN410	1.0
1575	CN368	-1.86262×10^2	1618	CN411	0.2
1576	CN369	6.46667×10^5	1619	CN412	0.1
1577	CN370	5.9066×10^4	1620	CN413	1.0
1578	CN371	4.30895×10^1	1621	CN414	0.75
1579	CN372	-1.89281×10^4	1622	CN415	1.0
1580	CN373	13.0944	1623	CN416	0.1
1581	CN374	-560.19	1624	CN417	0.05
1582	CN375	51.3345	1625	CN418	0.09
1583	CN376	15.477	1626	CN419	3.0
1584	CN377	-56.6515	1627	CN420	0.549
1585	CN378	4.95646	1628	CN421	0.734
1586	CN379	3.6186	1629	CN422	4.0
1587	CN380	1.8549	1630	CN423	0.607
1588	CN381	6.8672	1631	CN424	0.824

L-No.	Symbol	Value	L-No.	Symbol	Value
532	CN425	2.5	1675	CN468	0.0063
1633	CN426	0.340	1676	CN469	0.010481
1634	CN427	0.387	1677	CN470	0.00268
1635	CN428	0.15	1678	CN471	0.00029
1636	CN429	0.6	1679	CN472	0.00919
1637	CN430	0.35	1680	CN473	0.00371
1638	CN431	0.333	1681	CN474	0.000477
1639	CN432	0	1682	CN475	0.01174
1640	CN433	0.3	1683	CN476	0.006083
1641	CN434	0.2	1684	CN477	0.001134
1642	CN435	0.2	1685	CN478	0.3
1643	CN436	0	1686	CN479	0.05
1644	CN437	0.4	1687	CN480	1
1645	CN438	0.1	1688	CN481	0
1646	CN439	0	1689	CN482	0.6
1647	CN440	0.15	1690	CN483	2
1648	CN441	1.0	1691	CN484	10
1649	CN442	1.0	1692	CN485	60
1650	CN443	0.15	1693	CN486	0.0025
1651	CN444	1,660	1694	CN487	0.1
1652	CN445	1.0	1695	CN488	1
1653	CN446	0.9	1696	CN489	1.5
1654	CN447	0.3	1697	CN490	1.5
1655	CN448	0.1	1698	CN491	0.47
1656	CN449	0.4	1699	CN492	0.0081
1657	CN450	1,460	1700	CN493	0.0063
1658	CN451	1.1	1701	CN494	0.1
1659	CN452	0.5	1702	CN495	1.0
1660	CN453	0.1	1703	CN496	20
1661	CN454	1.0	1704	CN497	0.1
1662	CN455	0.567	1705	CN498	0.01
1663	CN456	0.979	1706	CN499	0.1
1664	CN457	1.5	1707	CN500	0.1
1665	CN458	4.0	1708	CN501	1
1666	CN459	1.75	1709	CN502	0.234
1667	CN460	0.15	1710	CN503	1.856
1668	CN461	1.0	1711	CN504	0
1669	CN462	1.5	1712	CN505	0.3
1670	CN463	1.0	1713	CN506	10
1671	CN464	1.05	1714	CN507	2
1672	CN465	1.0	1715	CN508	1
1673	CN466	1.0	1716	CN509	1.06
1674	CN467	0.0081	1717	CN510	0.004

L-No.	Symbol	Value	L-No.	Symbol	Value
1718	CN511	0.016			
1719	CN512	0.001			
1720	CN513	0.25			
1721	CN514	0.2			
1722	CN515	0.57			
1723	CN516	0.55			
1724	CN517	0.51			
1725	CN518	0.382			
1726	CN519	0.5			
1727	CN520	1.5365			
1728	CN521	-1.2901			
1729	CN522	1.5754			
1730	CN523	-1.4098			
1731	CN524	5			
1732	CN525	0.0001			
1733	CN526	0.5			
1734	CN527	1.06			
1735	CN528	1.06			
1736	CN529	0.05			
1737	CN530	0.2			
1738	CN531	0.75			
1739	CN532	0.9			
1740	CN533	0.125			
1741	CN534	1.4			
1742	CN535	0.0001			
1743	CN536	0.325			
1744	CN537	0.5			
1745	CN538	5.15			
1746	CN539	10			
1747	CN540	10			

1. <u>Nozzle Optional Input Tables</u>--Tables 2 thru 10 contain nozzle optional input data in tabular form.

Values specified in the table will be used unless they are overridden by input.

Parameters in the table with no specified value will be calculated unless a value is input.

TABLE 2

NOZZLE OPTIONAL INPUT FOR NOZZLE INSULATION DESIGN

Boundary station	Intermediate station	L-No. of EPS L-No. are consecutive from left to right	Expansion ratio	Axial distance downstream of throat	Radius from axis	Mach number	Static pressure	Erosion factor of safety	Erosion rate multiplier	Erosion rate of liner	Eroded liner thickness	Char factor of safety	Charred liner thickness	Virgin liner thickness at end of firing	Total liner thickness at ignition	Required backup insulation thickness	Boundary matching flag	Extra backup necessary for match at TTOT	Total backup thickness	Total thickness (liner and backup)
BDST	INST	L-No.	EPS	X	R	M	PS	FSE	MOD	XDOT	TLE	FSC	TLC	TLV	TL	TBU	A	TBM	TB	TTOT
1		126						*	1			*								
	1.1	144						1.25	1			1								
	1.2	162						1.25	1			1								
2UP		180						*	1			*					1			
2DN		198						*	1			*					1			
	2.1	216						1.25	1			1								
	2.2	234						1.25	1			1								
3UP		252						*	1			*								
3DN		270						1.25	1			1								
3.5UP		288						1.25	1			1					1			
3.5DN		306						1.25	1			1					0			
4UP		324						1.5	1			1								
4DN		342						1.5	1			1								
5UP		360						1.5	1			1					1			
5DN		378						1.5	1			1					1			
5.5		396						1.5	1											
6		414						1.5	1			1								
6.5		432						1.5	1											
7UP		450						1.5	1			1					1			
7DN		468						1.25	1			1					1			
	7.1	486						1.25	1			1								
	7.2	504						1.25	1			1								
8UP		522						1.25	1			1					1			
8DN		540						1.25	1			1					1			
	8.1	558						1.25	1			1								
	8.2	576						1.25	1			1								
14UP		594						1.25	1			1					1			
14DN		612						1.25	1			1					1			
	14.1	630						1.25	1			1								
	14.2	648						1.25	1			1								
15		666						1.25	1			1								
	SL	684						1.50	1			1								
	UNITS		-	in	in	-	psi	-	-	mil/sec	in.	-	in.	in.	in.	in.	-	in.	in	in.

ASSIGNMENT OF STATION NUMBERS, NOZZLE

Station		Station	
1	Face of flange mating with motor (except DESIG 123 and TYPNOZ = 6)	6	Throat
1.1	Intermediate insulation station	6.5	Throat insert, aft boundary
1.2	Intermediate insulation station	7UP	Insulation boundary, upstream side
2UP	Insulation boundary upstream side	7DN	Insulation boundary, downstream side
2DN	Insulation boundary, downstream side	7.1	Intermediate insulation station
2.1	Intermediate insulation station	7.2	Intermediate insulation station
2.2	Intermediate insulation station	8UP	Insulation boundary, upstream side
3UP	Insulation boundary upstream side	8DN	Insulation boundary downstream side
3DN	Insulation boundary, downstream side	8.1	Intermediate insulation station
3.5UP	Insulation boundary, upstream side	8.2	Intermediate insulation station
3.5DN	Insulation boundary, downstream side	9	Structural boundary
4UP	Blast tube exit TYPNOZ = 2, 4. Nose tip TYPNOZ = 1, 6	11	Center of injection port on ID of nozzle
4DN	Nose tip TYPNOZ = 1, 5, 6	12	Structural boundary
5UP	Insulation boundary	14UP	Insulation boundary, upstream side
5DN	Insulation boundary TYPNOZ = 1, 3 5, 6, 7 Nose tip TYPNOZ = 2, 4	14DN	Insulation boundary, downstream side
5.5	Throat insert forward boundary	14.1	Intermediate insulation station
		14.2	Intermediate insulation station
		15	Exit plane

*See Note 1 on next page

TABLE 3

NOZZLE OPTIONAL INPUT FOR INSULATION SECTIONS

Nozzle Section	L-No.	Liner Code	Liner Weight	Backup Code	Backup Weight	Total Weight
1-2	702	Note 1	--	Note 1	--	--
2-3	707	7	--	3	--	--
2-3.5	712	7	--	3	--	--
3-4	717	7	--	3	--	--
3.5-4	722	7	--	3	--	--
4-5	727	7	--	3	--	--
5-7	732	Note 2	--	3	--	--
Insert	737	7	--	--	--	--
7-8	742	7	--	3	--	--
8-14	747	7	--	3	--	--
14-15	752	7	--	3	--	--

The L-No. given is for the liner code. Additional L-No. are consecutive from left to right.

The value specified will be used unless overridden by input.

See the following table for insulation material liner and backup codes.

Note 1:

Nozzle Type	Liner Code	Backup Code	Additional Table Changes
2, 3, 4, 7	7	3	None
1, 5, 6	9	9	FSE = 1.5, FSC = 1.5 at 1, 2UP, 2DN, 3UP if not input

Note 2:

Throat Code	Liner Code
1, 2, 4	4
3	7

TABLE 4

NOZZLE OPTIONAL INPUT FOR INSULATION MATERIALS

Material Code	Material	L-No.	Virgin Density	Char Density	L-No.	Backup Thickness
1	Graphite cloth phenolic	757	0.0521	0.0376	243[illegible]	0.417
2	Silica cloth phenolic	759	0.0632	0.0509	2433	0.25
3	Glass cloth phenolic	761	0.066	0.0538	2434	0.204
4	High density graphite	763	0.0686	0	2435	1
5	Pyrolytic graphite	765	0.0777	0	2436	1
6	Tungsten	767	0.698	0	2437	0.3
7	Carbon cloth phenolic	769	0.0521	0.0376	2438	0.333
8	Asbestos cloth phenolic	771	0.0637	0.0509	2439	0.25
9	Filled buna rubber	773	0.0464	0.023	2440	0.3
10	Carbon-carbon composite	775	0.0506	0	2441	1
11	Porous tungsten	777	0.5584	0	2442	0.3
12	Pyrolytic graphite coating	779	0.0777	0	2443	0.5
13	Available	781	0	0	2444	0.333
14	Available	783	0	0	2445	0.333
15	Available	785	0	0	2446	0.25
		Units	lb/cu in.	lb/cu in.		

The L-No. given preceding the density is for the virgin density. Add one to that L-No. for the corresponding char density. The backup thickness L-No. is given preceding its value. (Backup thickness is the same as CN343 thru CN357.) The backup thickness stored is based on a 60 sec firing. Erosion for materials 13 and 14 is proportional to the calculated erosion for material 1 by the ratios CN340 and CN341, respectively (e.g., erosion (13) = erosion (1) * CN340). The desired ratios must be input for CN340 and CN341. Char calculation is identical to that calculated for material 1.

Erosion for material 15 is proportional to material 2 by the ratio CN342. Char calculation is identical to that calculated for material 2.

L-No.	Symbol	Value
2429	CN340	1
2430	CN341	1
2431	CN342	1

TABLE 5

NOZZLE OPTIONAL INPUT FOR STRUCTURAL RINGS

Base Symbol	L-No.	Safety factor FS	Material code	X to centroid XC	R to centroid RC	Axial length LA	Radial thickness TR	Weight	Minimum thickness MT	Symbol suffix
Flange	787	1.25	2	C	C	C	C	--	0.3	FL
Fixed ring	795	1.25	2	C	C	C	C	--	0.2	FR
Fixed extension	803	1.25	2	C	C	C	C	--	0.2	FE
Movable ring	811	1.25	2	C	C	C	C	--	0.2	MR
Movable extension	819	1.25	2	C	C	C	C	--	0.2	ME
Exit ring	827	1.25	2	C	C	C	C	--	0.2	ER
Gimbal ring	835	1.25	2	C	C	C	C	--	0.25	GR
Forward end ring	843	1.25	2	C	C	C	C	--	0.2	FER
Aft end ring	851	1.25	2	C	C	C	C	--	0.2	AER
Fixed connector	859	1.25	2	C	C	C	C	--	0.2	FC
Flange adapter	867	1.25	2	C	C	C	C	--	0.2	FA
Flexible bearing shims	875	1.25	11	--	--	--	--	--	--	FBS
	Units	--	--	in.	in.	in.	in.	lb	in.	

The L-No. given are for the safety factor. Additional L-No. are consecutive from left to right.

TABLE 6

NOZZLE OPTIONAL INPUT FOR STRUCTURAL SHELLS

	L-No.	Safety factor	Material code	Axial upstream station	Axial downstream station	Upstream thickness	Downstream thickness	Weight	Minimum thickness
WS 1-2	883	1.25	2	C	C	C	C	--	0.1
WS 2-3	891	1.25	2	C	C	C	C	--	0.1
WS 7-9	899	1.25	2	C	C	C	C	--	0.1
WS 9-12	907	1.25	2	C	C	C	C	--	0.1
WS 7-12	915	1.25	2	C	C	C	C	--	0.1
WS 12-15	923	1.25	6	C	C	C	C	--	0.05
	Units	--	--	in.	in.	in.	in.	lb	in.

The L-No. given are for the safety factor. Additional L-No. are consecutive from left to right.

TABLE 7

NOZZLE OPTIONAL INPUT FOR SPECIAL STRUCTURAL STATIONS

	L-No.	Axial Location	Radial Location
Station 9	931	C	C
Station 12	933	C	C
	Units	in.	in.

The L-No. given are for the axial location. Additional L-No. are consecutive from left to right.

TABLE 8

NOZZLE OPTIONAL INPUT FOR STRUCTURAL MATERIALS

	Material code	L-No.	Density	Modulus	Design strength	Compressive yield	Poisson's ratio
			ρST	YMOD	DS	CYS	μST
Maraging steel	1	935	0.[illegible]	27×10^6	215×10^3	200×10^3	0.3
180,000 ultimate steel	2	940	0.[illegible]	29×10^6	180×10^3	179×10^3	0.3
90,000 ultimate steel	3	945	0.[illegible]	[illegible] $\times 10^6$	90×10^3	70×10^3	0.3
6Al-4V Titanium	4	950	0.160	[illegible].5 $\times 10^6$	160×10^3	155×10^3	0.31
7075-T652 Aluminum	5	955	0.101	10.5×10^6	70×10^3	63×10^3	0.33
Structural fiberglass	6	960	0.070	4×10^6	60×10^3	45×10^3	0.2[illegible]
Beryllium	7	965	0.066	42.5×10^6	40×10^3	30×10^3	0.3
Molybdenum	8	970	0.368	47×10^6	90 x 10[illegible]	90×10^3	0.3
Columbium	9	975	0.310	15×10^6	40×10^3	40×10^3	0.3
304 stainless steel	10	980	0.286	28×10^6	125×10^3	55×10^3	0.3
17-7 PH steel	11	985	0.276	29×10^6	170×10^3	160×10^3	0.3
Waspaloy	12	990	0.296	31×10^6	180×10^3	112×10^3	0.31
available	13	995	0	0	0	0	0
available	14	1000	0	0	0	0	0
available	15	1005	0	0	0	0	0
available	16	1010	0	0	0	0	0
available	17	1015	[illegible]	0	0	0	0
Flexible seal elastomer	18	1020	0.047	24	500	--	0.4998
		Units	lb/cu in.	psi	psi	psi	--

The L-No. given are for the density. Additional L-No. are consecutive from left to right.

TABLE 9

NOZZLE OPTIONAL INPUT FOR SPECIAL INSULATION RINGS

	L-No.	Material code	X to centroid	R to centroid	Axial length	Radial thickness	Weight	Symbol suffix
Base Symbol			XC	RC	LA	TR		
Splitline insulator	1025	*	C	C	C	C	--	SLI
Cavity insulator	1031	*	C	C	C	C	--	CI
Splitline filler	1037	**	C	C	C	C	--	TRI
Fixed adapter insulator	1043	***	C	C	C	C	--	AI
Exit ring insulator	1049	***	C	C	C	C	--	ERI
Fixed ring insulator	1055	***	C	C	C	C	--	FRI
	Units	--	in.	in.	in.	in.	lb	

The L-No. given are for the material code. Additional L-No. are consecutive from left to right.

---

*Uses backup code at 7-8 in Table 3 if not input.

**DESIG 252 uses backup code at 5-7 in Table 3; if not input, other DESIGS uses backup code at 7-8.

***Uses liner code at 3-4 in Table 3 if not input.

TABLE 10

NOZZLE OPTIONAL INPUT FOR
SPECIAL MATERIALS AND EXIT RING WALLS STATIONS

Special Materials

Definition	L-No.	Value	Units
Density of homeycomb core	1061	0.00266	lb/cu in.
Honeycomb inner facing material code	1063	10	--
Honeycomb outer facing material code	1064	10	--

Honeycomb structure is obtained by specifying a structural material code of 20 in Table 6 .

Exit Ring Walls

L-No.	Symbol	Definition	Value	Fortran Symbol
1065	TBWL	Wall thickness, axial	(C) in.	TBWL
1066	THWL	Wall thickness, radial	(C) in.	THWL

TABLE 11

NOZZLE OPTIONAL INPUT FOR PINTLE NOZZLE DESIGN

Symbol	Definition	L-No.	Safety Factor	Material Code	Insulation* or Structural	Weight
PNT	Pintle	1396	1.25	6	I	--
SRT	Insert	1399	1.25	6	I	--
IIN	Insert insulation	1402	1.5	7	I	--
CB	Centerbody	1405	1.5	1	I	--
SS	Sliding seal	1408	1.25	12	S	--
PL	Pintle liner	1411	1.5	10	I	--
PIN	Pintle insulation	1414	1.5	7	I	--
SM	Structural member	1417	1.25	2	S	--
PH	Pintle housing	1420	1.5	7	I	--
ACTPST	Actuator piston	1423	1.25	11	S	--
ACTH	Actuator housing	1426	1.25	11	S	--
CSS	Center shaft structure	1429	1.25	2	S	--
CSI	Center shaft insulation	1432	1.5	7	I	--
MH	Movable housing	1435	1.25	2	S	--
CBWS	Centerbody wall structure	1438	1.25	2	S	--
CBWI	Centerbody wall insulation	1441	1.5	7	I	--
CBDS	Centerbody dome structure	1444	1.25	2	S	--
CBDI	Centerbody dome insulation	1447	1.5	7	I	--
STTS	Strut structure	1450	1.25	2	S	--
STTI	Strut insulation	1453	1.5	7	I	--
SSR	Strut support ring	1456	1.25	2	S	--

The L-No. given is for the safety factor. Additional L-No. are consecutive from left to right excluding the insulation or structure column.

---

* I means the material specified by the material code is found in the insulation materials table.
S means the material is found in the structural materials table.

TABLE 12

NOZZLE OPTIONAL INPUT FOR PINTLE NOZZLE DESIGN,
COMPRESSIVE YIELD STRENGTHS OF MATERIALS

			Compressive Yield Strength as a Function of Temperature							
		L-No. 1487	Temperature (°R)							
Material	L-No.	Material Code	540	860	1,260	1,660	2,060	3,460	4,960	6,460
			Compressive Yield Strength							
Graphite cloth phenolic	1495	1	10,000	8,500	5,000	3,700	3,300	0	0	0
Tungsten	1504	6	100,000	100,000	76,000	55,500	40,500	14,000	5,000	100
Available	1513	0	0	0	0	0	0	0	0	0
Available	1522	0	0	0	0	0	0	0	0	0
17-7 PH steel	1531	11	160,000	150,000	114,900	35,500	0	0	0	0
Waspaloy	1540	12	112,000	108,000	106,000	104,000	78,000	0	0	0
Available	1549	0	0	0	0	0	0	0	0	0
Available	1558	0	0	0	0	0	0	0	0	0

L-No. 1487 is given for the first temperature. The rest of the L-No.'s given is for material code and compressive yield strength. Additional L-No.'s are consecutive from left to right.

The first four lines of the table are reserved for insulation materials. The last four lines are for structural materials.

3. TORQUE INPUT

a. Nozzle Torque Optional Input

L-No.	Symbol	Definition	Value	Fortran Symbol
5750	CTR1	O-ring friction coefficient due to compression	2.5	CTR1
5751	PBP1	Ratio of base to free stream static pressure	0.5	PBP1
5752	MU	Friction coefficient (steel on Teflon)	0.05	XMU
5753	TAMP	Internal aerodynamic torque amplification factor	(C)*	TAMP

Equation Constants

L-No.	Symbol	Definition	Value	Fortran Symbol
5754	TFT2	Friction torque multiplier (subsonic split external/ ball and socket)	2	TFT2
5755	TFT2S	Friction torque multiplier (subsonic split external, submerged and external SSSL/gimbal)	2.5	TFT25
5756	TFT1	Friction torque multiplier (integral movable, submerged and external SSSL/gimbal)	1	TFT1
5757	GMAX	Nozzle movable portion acceleration	1	GMAX
5758	CT2	Gravitational torque	0	CT1
5759	CT2	Flexible bearing seal torque multiplier for boot torque	0.15	CT2

*C indicates that if value is not input, it will be calculated in the program.

L-No.	Symbol	Definition	Value	Fortran Symbol
5760	CT3	Effective shear modulus for steel shims	-0.2595×10^{-6}	CT3
5761	CT4	Effective shear modulus for glass shims	-0.29×10^{-6}	CT4
5762	CT5	Flexible bearing boot torque	1	CT5
5763	CT6	Flexible bearing boot torque	0	CT6

4. LIQUID INJECTION INPUT

a. Liquid Injection Performance Routine Input

L-No.	Symbol	Definition	Value	Fortran Symbol
2020	--	TVC = 0, biaxial TVC is not required =1, biaxial TVC is required	1	BATVC
2021	--	Method TYPINJ 1, 2, 3, 4 TYPINJ 5-11 = 1, standard method = 2, alternate method	 1 2	OPTMTD
2022	TYPINJ	Injectant =1, Freon 113 =2, Freon 114B2 =3, Freon 114I2 =4, N_2O_4 =5, $Sr(ClO_4)_2 + H_2O$ =6, $Pb(ClO_4)_2 + H_2O$ =7, $Sr(ClO_4)_2 + CH_3OH$ =8, $Sr(ClO_4)_2 + C_2H_5OH$ =9, N_2H_4 =10, UDMH =11, 50-50 N_2H_4/UDMH	4	TYPINJ

The following three parameters are input only if standard method is requested.

L-No.	Symbol	Definition	Value	Fortran Symbol
2023	NQUADU	Number of quadrants being utilized	4	XNQ
2024	DTIME	Integration interval	1 sec	DTIME
2025	BETA-Q	Angle spanned per quadrant by injectant ports	75 deg	BETA

The following seven parameters are input only if the alternate method of calculation is specified. If they are not input here, they will be set from data in the duty cycle.

L-No.	Symbol	Definition	Value	Fortran Symbol
2026	DEL-AVG	Average thrust deflection angle of duty cycle	0 deg	DELAVG
2027	FS/FPV-A	Ratio of side force to primary vacuum thrust at average thrust deflection angle	0	FSFAAV
2028	FS/FPV-M	Ratio of side force to primary vacuum thrust at maximum thrust deflection angle	0	FSFAMX
2029	WDOTP-MAX	Maximum flow rate of primary motor	0 lb/sec	WAMXDT
2030	ISPVAC	Primary motor vacuum specific impulse	0 sec	XISPPM
2031	IV	Total vehicle vacuum thrust impulse	0 lb-sec	XIV
2032	KDELT	Ratio of control thrust impulse to total vehicle vacuum thrust impulse	0	XKDEL

LITVC Actuation

L-No.	Symbol	Definition	Value	Fortran Symbol
2040	--	Hydraulic fluid =0, injectant not used as hydraulic fluid =1, injectant used as hydraulic fluid	0	CNTFLD
2041	--	Pressurization =0, select minimum weight system =+1, warm gas pressurization =−1, integral warm gas pressurization =+2, cold gas pressurization =−2, integral cold gas pressurization	0	PRESTP
2042	--	Actuator =0, select minimum weight system =1, warm gas motor pump =2, electric motor pump =3, cold gas blowdown =4, warm gas blowdown =5, electromechanical	0	TLITVC
2043	--	Cold gas tank shape =0, select minimum weight =1, spherical tank =2, toroidal tank	0	TCGSHP
2044	--	Injectant tank shape =0, select minimum weight tank =1, spherical tank =2, toroidal tank	0	TNKSHP
2045	--	Tank material =0, select minimum weight =1, steel tanks =2, titanium tanks =3, fiberglass tanks	0	TNKMAT

b. Liquid Injection Performance Optional Input

L-No.	Symbol	Definition	Value	Fortran Symbol
3230	NPV	Number of pintle injector valves utilized per quadrant	(C)*	PVQN
3231	IF	Control thrust impulse	(C) sec	XIF
3232	KONE	Empirical constant to determine unexpendable injectant	0.03	XKBT
3233	KTWO	Empirical constant to determine injectant total requirements	0.03	XKPB
3234	KTRI	Empirical constant to determine injectant total requirements	0.1	XKUL

LITVC Actuation

L-No.	Symbol	Definition	Value	Fortran Symbol
4180	CV	Orifice coefficient for pintle	0.98	CVP
4181	SF	Safety factor for injectant tank	1.5	FSIT
4182	SFCG	Safety factor for cold gas tank	1.5	FSCGT
4183	FU	Ultimate tensile strength of tubing	100,000 psi	FUL
4184	FUG	Ultimate strength of warm gas tubing	27,000 psi	FUWGL
4185	FY	Yield strength	60,000 psi	FYL
4186	FYG	Yield strength of warm gas tubing	17,000 psi	FYWGL
4137	HAD	Adiabatic head	556,000 ft	HADL
4188	MW	Molecular weight of warm gas	19.24	XMWWG
4189	NSFGT	Safety factor for gas tubing	4	FSGL
4190	NSFIT	Safety factor for injectant tubing	4	FSIL
4191	NSFT	Safety factor for hydraulic tubing	4	FSHL

*C indicates that if value is not input, it will be calculated in the program.

LITVC Actuation (Cont)

L-No.	Symbol	Definition	Value	Fortran Symbol
4192	PA	Atmospheric pressure	14.7 psi	PAMB
4193	PLINE	Pressure loss in injectant lines	25 psi	PRESLN
4194	PSU	Hydraulic supply pressure	3,000 psi	PS
4195	PFREE	Nozzle free stream pressure at injector	25 psi	PFREE
4196	TI	Temperature of injectant (initial)	530	TEMI
4197	VHO	Velocity of hydraulic oil	240 in./sec	VELHO
4198	VINJ	Velocity of injectant flow	200 ft/sec	VELINJ
4199	WPT	Weight of pressure transducers	1 lb	WPT
4200	ETAMP	Efficiency of warm gas motor pump	0.35	ETAMP
4201	RHOG	Density of warm gas	0.000463 lb/cu in.	RHOG
4202	RHOH	Density of hydraulic oil	0.03 lb/cu in.	RHOH
4203	RHO1T	Density of steel tank material	0.283 lb/cu in.	RHOTTB (1)
4204	RHO2T	Density of titanium tank material	0.17 lb/cu in.	RHOTTB (2)
4205	RHO3T	Density of fiberglass tank material	0.07 lb/cu in.	RHOTTB (3)
4206	SU1	Ultimate strength for steel tank	232,000 psi	SUITAB (1)
4207	SU2	Ultimate strength for titanium tank	110,000 psi	SUITAB (2)
4208	SU3	Ultimate strength for fiber-glass tank	92,000 psi	SUITAB (3)

TABLE 13 TBLI3(61)

FREON FORCE RATIO VS FLOW RATIO PERFORMANCE

No. of Injectors Per Quadrant							
1		3		5			
L-No.	FS/FPV	L-No.	FS/FPV	L-No.	FS/FPV	L-No.	WDOTS/ WDOTP
3241	0	3256	0	3271	0	3286	0
3242	0.0095	3257	0.0095	3272	0.0095	3287	0.02
3243	0.0205	3258	0.022	3273	0.0227	3288	0.05
3244	0.0275	3259	0.03	3274	0.0305	3289	0.07
3245	0.0338	3260	0.0374	3275	0.0382	3290	0.09
3246	0.0398	3261	0.044	3276	0.0455	3291	0.11
3247	0.0452	3262	0.0497	3277	0.052	3292	0.13
3248	0.0498	3263	0.055	3278	0.0584	3293	0.15
3249	0.0535	3264	0.06	3279	0.064	3294	0.17
3250	0.0567	3265	0.0642	3280	0.0687	3295	0.19
3251	0.058	3266	0.066	3281	0.0702	3296	0.20

L-No.	Definition	Value
3240	Number of WDOTS/WDOTP values in table.	11

Maximum number of points = 15

TABLE 14

TBLI4(186)

N_2O_4 FORCE RATIO VS FLOW RATIO PERFORMANCE

No. of Injectors

1				2				3			
L-No.	FS/FPV	L-No.	WDOTS/ WDOTP	L-No.	FS/FPV	L-No.	WDOTS/ WDOTP	L-No.	FS/FPV	L-No.	WDOTS/ WDOTP
3302	0.	3317	0.	3333	0.	3348	0.	3364	0.	3379	0.
3303	0.005	3318	0.004	3334	0.007	3349	0.0048	3365	0.0115	3380	0.008
3304	0.0115	3319	0.01	3335	0.018	3350	0.015	3366	0.0203	3381	0.016
3305	0.017	3320	0.017	3336	0.024	3351	0.022	3367	0.028	3382	0.024
3306	0.023	3321	0.026	3337	0.033	3352	0.034	3368	0.038	3383	0.036
3307	0.029	3322	0.037	3338	0.042	3353	0.048	3369	0.051	3384	0.054
3308	0.0327	3323	0.045	3339	0.051	3354	0.064	3370	0.06	3385	0.068
3309	0.038	3324	0.06	3340	0.056	3355	0.074	3271	0.067	3386	0.08
3310	0.0402	3325	0.067	3341	0.061	3356	0.086	3372	0.075	3387	0.095
				3342	0.064	3357	0.094	3373	0.0822	3388	0.112

No. of Injectors

4				5				6			
L-No.	FS/FPV	L-No.	WDOTS/ WDOTP	L-No.	FS/FPV	L-No.	WDOTS/ WDOTP	L-No.	FS/FPV	L-No.	WDOTS/ WDOTP
3395	0.	3410	0.	3426	0.	3441	0.	3457	0.	3472	0.
3396	0.0115	3411	0.008	3427	0.0115	3442	0.008	3458	0.0115	3473	0.008
3397	0.021	3412	0.016	3428	0.021	3443	0.016	3459	0.021	3474	0.016
3398	0.029	3413	0.024	3429	0.0295	3444	0.024	3460	0.03	3475	0.024
3399	0.039	3414	0.035	3430	0.04	3445	0.035	3461	0.04	3476	0.034
3400	0.05	3415	0.049	3431	0.0525	3446	0.05	3462	0.056	3477	0.052
3401	0.06	3416	0.063	3432	0.0645	3447	0.066	3463	0.068	3478	0.0665
3402	0.068	3417	0.075	3433	0.075	3448	0.0815	3464	0.076	3479	0.077
3403	0.079	3418	0.093	3434	0.086	3449	0.099	3465	0.0885	3480	0.095
3404	0.085	3419	0.1045	3435	0.097	3450	0.119	3466	0.095	3481	0.105
3405	0.092	3420	0.119	3436	0.106	3451	0.137	3467	0.109	3482	0.129
3406	0.0963	3421	0.13	3437	0.1138	3452	0.15	3468	0.118	3483	0.146
				3438	0.1155	3453	0.161	3469	0.125	3484	0.161
								3470	0.13	3485	0.173

L-No.	Definition
3301	No. of points corresponding to 1 injector - 9
3332	No. of points corresponding to 2 injectors - 10
3363	No. of points corresponding to 3 injectors - 10
3394	No. of points corresponding to 4 injectors - 12
3425	No. of points corresponding to 5 injectors - 13
3456	No. of points corresponding to 6 injectors - 14

Maximum No. of points = 15

TABLE 15

FREON AND N_2H_4 - UDMH FORCE RATIO
VS SECONDARY SPECIFIC IMPULSE PERFORMANCE

No. of Injectors

1				3				5			
L-No.	FS/FPV	L-No.	ISPS	L-No.	FS/FVP	L-No.	ISPS	L-No.	FS/FPV	L-No.	ISPS
3488	0.0075	3503	142	3519	0.0082	3534	152	3550	0.0082	3565	152
3489	0.01	3504	134	3520	0.012	3535	138	3551	0.012	3566	138
3490	0.013	3505	127	3521	0.016	3536	128	3552	0.016	3567	128
3491	0.016	3506	121	3522	0.023	3537	116	3553	0.023	3568	116
3492	0.02	3507	112	3523	0.0325	3538	104	3554	0.033	3569	104
3493	0.028	3508	104	3524	0.043	3539	94	3555	0.043	3570	96
3494	0.036	3509	96	3525	0.0535	3540	86	3556	0.063	3571	84
3495	0.052	3510	84	3526	0.073	3541	74	3557	0.08	3572	78

L-No.	Definition	Value
3487	No. of points corresponding to 1 injector =	8
3518	No. of points corresponding to 3 injectors =	8
3549	No. of points corresponding to 5 injectors =	8

Maximum No. of points = 15

TABLE 16

TBLJ11(186)

N_2O_4 FORCE RATIO VS SECONDARY SPECIFIC IMPULSE PERFORMANCE

No. of Injectors

1				2				3			
L-No	FS/FPV	L-No.	ISPS	L-No.	FS/FPV	L-No.	ISPS	L-No.	FS/FPV	L-No.	ISPS
3581	0.008	3596	322	3612	0.008	3627	322	3643	0.008	3658	322
3582	0.009	3597	294	3613	0.011	3628	304	3644	0.0135	3659	304
3583	0.011	3598	272	3614	0.017	3629	277	3645	0.0200	3660	286
3584	0.015	3599	240	3615	0.023	3630	254	3646	0.0285	3661	264
3585	0.020	3600	210	3616	0.029	3631	235	3647	0.0365	3662	246
3586	0.025	3601	188	3617	0.037	3632	212	3648	0.0470	3663	224
3587	0.028	3602	178	3618	0.045	3633	192	3649	0.0600	3664	200
				3619	0.050	3634	180	3650	0.0720	3665	180

No. of Injectors

4				5				6			
L-No	FS/FPV	L-No.	ISPS	L-No.	FS/FPV	L-No.	ISPS	L-No.	FS/FPV	L-No.	ISPS
3674	0.008	3689	322	3705	0.008	3720	322	3736	0.008	3751	322
3675	0.0185	3690	296	3706	0.018	3721	302	3737	0.018	3752	301
3676	0.0250	3691	282	3707	0.0255	3722	288	3738	0.024	3753	291
3677	0.0340	3692	264	3708	0.0350	3723	272	3739	0.031	3754	283
3678	0.0485	3693	238	3709	0.0460	3724	254	3740	0.040	3755	270
3679	0.0630	3694	214	3710	0.0600	3725	233	3741	0.139	3756	138
3680	0.0870	3695	178	3711	0.1020	3726	172				

L-No.	Definition	Value
3580	No. of points corresponding to 1 injector	7
3611	No. of points corresponding to 2 injectors	8
3642	No. of points corresponding to 3 injectors	8
3673	No. of points corresponding to 4 injectors	7
3704	No. of points corresponding to 5 injectors	7
3735	No. of points corresponding to 6 injectors	6

Maximum No. of points 15

TABLE 17 TBLI12(62)

$Sr(ClO_4)_2 + H_2O$ FORCE RATIO
VS SECONDARY SPECIFIC IMPULSE PERFORMANCE

(70 to 74 Weight Percent)

No. of Injectors

1				3			
L-No.	FS/FPV	L-No.	ISPS	L-No.	FS/FPV	L-No.	ISPS
3767	0.009	3782	170	3798	0.009	3813	230
3768	0.011	3783	157	3799	0.013	3814	210
3769	0.015	3784	141	3800	0.019	3815	186
3770	0.019	3785	128	3801	0.0235	3816	170
3771	0.025	3786	112	3802	0.031	3817	148
3772	0.0315	3787	100	3803	0.036	3818	136
3773	0.0405	3788	86	3804	0.0435	3819	122
3774	0.0490	3789	76	3805	0.049	3820	115
				3806	0.058	3821	106
				3807	0.0685	3822	98

L-No.	Description	Value
3766	No. of points corresponding to 1 injector =	8
3797	No. of points corresponding to 3 injectors =	10

Maximum No. of points = 15

TABLE 18 TBLI13(62)

Pb $(ClO_4)_2$ + H_2O FORCE RATIO
VS SECONDARY SPECIFIC IMPULSE PERFORMANCE

(70 to 74 Weight Percent)

No. of Injectors

1				3			
L-No.	FS/FPV	L-No.	ISPS	L-No.	FS/FPV	L-No.	ISPS
3829	0.009	3844	150	3860	0.012	3875	192
3830	0.011	3845	142	3861	0.017	3876	174
3831	0.014	3846	132	3862	0.023	3877	156
3832	0.020	3847	117	3863	0.029	3878	140
3833	0.027	3848	103	3864	0.0345	3879	128
3834	0.038	3849	86	3865	0.041	3880	116
3835	0.049	3850	72	3866	0.0475	3881	108

L-No.	Description	Value
3828	No. of points corresponding to 1 injector =	7
3859	No. of points corresponding to 3 injectors =	7

Maximum No. of points = 15

TABLE 19 TBLI14(31)

Sr $(ClO_4)_2$ + C_2H_5OH FORCE RATIO
VS SECONDARY SPECIFIC IMPULSE PERFORMANCE

(One Injector)

L-No.	FS/FPV	L-No.	ISPS
3891	0.01	3906	223
3892	0.013	3907	209
3893	0.018	3908	190
3894	0.025	3909	169
3895	0.033	3910	147
3896	0.039	3911	133
3897	0.047	3912	117
3898	0.053	3913	108

L-No.	Description		Value
3890	No. of points in Table	=	8

Maximum No. of points = 15

TABLE 20 TBLI15(31)

$Sr(ClO_4)_2 + CH_3OH$ FORCE RATIO VS SECONDARY SPECIFIC IMPULSE PERFORMANCE

(One Injector)

L-No.	FP/FPV	L-No.	ISPS
3922	0.01	3937	155
3923	0.013	3938	144
3924	0.017	3939	133
3925	0.023	3940	119
3926	0.03	3941	105
3927	0.037	3942	92
3928	0.045	3943	80
3929	0.052	3944	72

L-No.	Description	Value
3921	No. of points in Table =	8

Maximum No. of points = 15

TABLE 21 TBLI5(15)

INJECTANT DENSITIES

L-No.	Density (lb/cu ft)	Injectant
3952	98	FREON 113
3953	134	FREON 114B2
3954	168	FREON 114I2
3955	89	N_2O_4
3956	130	$Sr(ClO_4)_2 + H_2O$
3957	162	$Pb(ClO_4)_2 + H_2O$
3958	105	$Sr(ClO_4)_2 + CH_3OH$
3959	97	$Sr(ClO_4)_2 + C_2H_3OH$
3960	63	N_2H_4
3961	49	UDMH
3962	56	50-50 (N_2H_4, UDMH)

Maximum No. of points = 15

5. HOT GAS PERFORMANCE INPUT

a. Hot Gas Routine Input

L-No.	Symbol	Definition	Value	Fortran Symbol
2000	$VALX_i$	Valve type	--	HGVAL
		=1, ablative pintle, sonic injection		
		=2, ablative pintle, supersonic injection		
		=3, ablative pintle, sonic injection (PL)		
		=4, noneroding pintle, supersonic injection		
		=5, noneroding pintle, sonic injection (PL)		
		=6, jet pipe valve, sonic injection		
		=7, jet pipe valve, supersonic injection		
		=8, rotating cylinder valve		
2001	ETAV	Valve cyclic rate	cps	ETAV
2002	AL_i	Pintle type	--	ALX
		=1, pressure balanced pintle		
		=2, nonpressure balanced pintle		
2003	AT_i	Actuator type	--	ATX
		=1, conventional actuation		
		=2, reverse actuator		
2004	BM_i	Pintle type	--	BMX
		=1, pintle without balancing		
		=2, pintle balanced with chamber pressure		
		=3, pintle balanced with pintle tip pressure		
2005	EC_i	Exit configuration approximation	--	ECX
		=1, conical exit		
		=2, contour exit (local angle)		
		=3, contour exit (average angle)		

L-No.	Symbol	Definition	Value	Fortran Symbol
2006	PT_i	Pintle type =1, clearance type pintle =2, seating type pintle	--	PTX
2007	SO_i	Servoactuator =1, 3 way servoactuator =2, 4 way servoactuator	--	SOX
2008	MM_i	Pintle mounting = 1, externally mounted pintle valve =2, closure mounted pintle valve =3, leg mounted pintle valve =4, plenum mounted pintle valve	--	XMMX
2009	AO	Geometric orifice flow area (input only if desired to duplicate performance of an existing valve)	sq in.	AOI

b. <u>Hot Gas Optional Input</u>

L-No.	Symbol	Definition	Value	Fortran Symbol
2450	ALPHACAPO	Flag to specify method of calculating thermal diffusivity for actuator cap insulation =1, calculate using average of thermal diffusivity =2, calculate using average of temperature	1	ACAPO
2451	ALPHACAPI	Flag to specify material used in actuator cap insulation =4, other =5, silica cloth =6, carbon cloth =7, asbestos =8, V-44	8	ACAPX

L-No.	Symbol	Definition	Value	Fortran Symbol
2452	ALPHAHOUO	Flag to specify method of calculating thermal diffusivity for valve housing =1, calculate using average of thermal diffusivity =2, calculate using average of temperature	1	AHOUO
2453	ALPHAHOUi	Flag to specify material used in valve housing =4, other =5, silica cloth =6, carbon cloth =7, asbestos =8, V-44	5	AHOUX
2454	ALPHALEGO	Flag to specify method of calculating thermal diffusivity for leg insulation =1, calculate using average of thermal diffusivity =2, calculate using average of temperature	1	ALEGO
2455	ALPHALEGi	Flag to specify material used in leg insulation =4, other =5, silica cloth =6, carbon cloth =7, asbestos =8, V-44	5	ALEGX
2456	ALPHALINO	Flag to specify method of calculating thermal diffusivity for duct insulation =1, calculate using average of thermal diffusivity =2, calculate using average of temperature	1	ALINO

L-No.	Symbol	Definition	Value	Fortran Symbol
2457	ALPHALINi	Flag to specify material used in duct insulation =4, other =5, silica cloth =6, carbon cloth =7, asbestos =8, V-44	6	ALINX
2458	ALPHAS	Valve orifice exit angle	3 deg	ALPHAS
2459	ALPHATIPO	Flag to specify method of calculating thermal diffusivity for pintle tip shell =1, calculate using average of thermal diffusivity =2, calculate using average of temperature	1	ATIPO
2460	ALPHATIPi	Flag to specify material used in pintle tip shell =1, tungsten =2, molybdenum =3, tantalum =4, other =5, silica cloth =6, carbon cloth =7, asbestos =8, V-44	1	ATIPX
2461	BEX	Bypass nozzle expansion angle	0 deg	BEX
2462	CDP	Sonic discharge coefficient (primary nozzle)	0.99	CDP
2463	CDV	Valve flow coefficient	(C)	CDV
2464	CMS	Secondary nozzle flow coefficient	0.854	CMS
2465	CSTARP	Characteristic velocity (primary flow)	5,200 ft/sec	CSTARP
2466	CSTARS	Characteristic velocity (valve flow)	5,200 ft/sec	CSTARS

L-No.	Symbol	Definition	Value	Fortran Symbol
2467	DNi	Nozzle throat diameter (flag) =1, initial nozzle throat diameter =2, average nozzle throat diameter =3, final nozzle throat diameter =4, nozzle throat diameter at DEL-M3	2	DNX
2468	dt	Time increment for integrations	0.05 sec	DTIME
2469	EDPT	Pintle tip erosion rate	0.025 in./sec	EDPT
2470	EPSD	Area ratio, duct to valve orifice	3	EPSD
2471	EPSV-N	Injection angle measured between the valve centerline and the upstream nozzle wall surface	90 deg	EPSVN
2472	ERRDL	Erosion rate of duct liner	0.01 in./sec	ERRDL
2473	ETA-NS	Injection port flow coefficient	0.96	ETANS
2474	CFB	Bypass nozzle thrust coefficient	(C)	CFB
2475	GAMMAP	Ratio of specific heats for nozzle exhaust	1.18	GAMMAP
2476	GAMMAS	Ratio of specific heats (valve gases)	1.18	GAMMAS
2477	GPRIME	Empirical constant	0.7	GPRIME
2478	OPTION	Flag =1, use iterative method for ETA-A =2, direct calculation for ETA-A	1.0	OPTION
2479	PERCENTLE	Percent leakage	5%	PERCNT
7480	RHOC	Approximate density of composite closure material	0.1 lb/cu in.	RHOC
2481	RHOLIN	Density of duct liner material	0.0652 lb/cu in.	RHOLIN

L-No.	Symbol	Definition	Value	Fortran Symbol
2482	RHOSH	Density of duct shell material	0.176 lb/cu in.	RHOSH
2483	REX/DSTARP	Valve orifice radius divided by nozzle throat diameter	(C)	RXDSP
2484	ST	Tensile strength of duct shell	93,000 lb/sq in.	ST
2485	TB	Time to web burnout	(C) sec	TB
2486	TF	Gas flame temperature	6,140° R	TF
2487	TIC	Initial cap backside temperature	540° R	TIC
2488	TIH	Initial housing backside temperature	540° R	TIH
2489	TIL	Initial leg backside temperature	540° R	TIL
2490	TIP	Initial backside pintle tip temperature	540° R	TIP
2491	TOC	Final cap backside temperature	660° R	TOC
2492	TOH	Final housing backside temperature	900° R	TOH
2493	TOL	Final leg backside temperature	660° R	TOL
2494	TOP	Final backside pintle temperature	1,460° R	TOP
2495	XMACHS	Valve injection Mach number	1.0	XMACHS
2496	N	Propellant burn rate exponent	0.3	XNPEX
2497	NV	Number of hot gas valves	4.0	XNV
2498	TFV	Hot gas valve flow time	(C) sec	TFV

c. Hot Gas Optional Input Constants

L-No.	Symbol	Value	L-No.	Symbol	Value
2510	CHG1	2	2538	CHG29	1
2511	CHG2	1	2539	CHG30	1
2512	CHG3	0	2540	CHG31	0.1
2513	CHG4	0.375	2541	CHG32	1
2514	CHG5	4	2542	CHG33	1
2515	CHG6	0	2543	CHG34A	2.1
2516	CHG7	0	2544	CHG34B	1.1
2517	CHG8	1.2	2545	CHG36	1
2518	CHG9	0	2546	CHG37	1
2519	CHG10	0	2547	CHG38	1
2520	CHG11	2	2548	CHG39	20
2521	CHG12	16	2549	CHG40	0
2522	CHG13	0	2550	CHG41	0
2523	CHG14	0	2551	CHG42	1
2524	CHG15	0	2552	CHG43	1
2525	CHG16	2.5	2553	CHG44	0 in.
2526	CHG17	0.7	2554	CHG45	0.2
2527	CHG18	0.43	2555	CHG46	1.1
2528	CHG19	1	2556	CHG47	3
2529	CHG20	0.95	2557	CHG48	0.4 in.
2530	CHG21	0.5	2558	CHG49	1 in.
2531	CHG22	0	2559	CHG50	0 in.
2532	CHG23	0.005	2560	CHG51	1
2533	CHG24	4	2561	CHG52	0.1 in.
2534	CHG25	1.2	2562	CHG53	90,000 lb/cu in.
2535	CHG26	1	2563	CHG54	0.5 in.
2536	CHG27	1	2564	CHG55	0 in.
2537	CHG28	1	2565	CHG56	1.3

L-No.	Symbol	Value	L-No.	Symbol	Value
2566	CHG57	0.55 in.	2574	CHG65	0
2567	CHG58	2 in.	2575	CHG66	1
2568	CHG59	1.5	2576	CHG67	1
2569	CHG60	0.5	2577	CHG[illegible]	0.5
2570	CHG61	0.25 in.	2578	CHG69	0.3 in.
2571	CHG62	0	2579	CHG70	1
2572	CHG63	1	2580	CHG71	1
2573	CHG64	0			

d. Hot Gas Input Data Tables--Additional hot gas input data are included in Tables 22 thru 36.

TABLE 22 THG1(31)

RATIO OF PINTLE DIAMETER TO VALVE ORIFICE DIAMETER VS VALVE ORIFICE DIAMETER FOR NONERODING VALVE

L-No.	Valve Orifice Dia (in.)	L-No.	Pintle Dia/Valve Orifice Dia (in.)
2601	0.00	2616	2.000
2602	0.25	2617	1.650
2603	0.50	2618	1.545
2604	1.00	2619	[illegible]
2605	1.50	2620	1.357
2606	2.00	2621	1.310
2607	3.00	2622	1.242
2608	4.00	2623	1.201
2609	5.00	2624	1.172
2610	6.00	2625	1.152
2611	7.00	2626	1.140
2612	8.00	2627	1.125
2613	9.00	2628	1.110
2614	20.00	2629	1.100

L-No.	Definition	Value
2600	Number of pairs in the table.	14

TABLE 23 THG2(31)

RATIO OF PINTLE DIAMETER TO VALVE ORIFICE DIAMETER VS VALVE ORIFICE DIAMETER FOR ABLATIVE VALVE

L-No.	Valve Orifice Dia (in.)	L-No.	Pintle Dia/Valve Orifice Dia (in.)
2632	0.00	2647	4.000
2633	0.50	2648	2.000
2634	1.00	2649	1.810
2635	1.50	2650	1.652
2636	2.00	2651	1.525
2637	2.50	2652	1.421
2638	3.00	2653	1.348
2639	3.50	2654	1.300
2640	4.00	2655	1.261
2641	5.00	2656	1.207
2642	6.00	2657	1.168
2643	7.00	2658	1.140
2644	8.00	2659	1.125
2645	9.00	2660	1.110
2646	20.00	2661	1.100

L-No.	Definition	Value
2631	Number of pairs in the table.	15

TABLE 24 THG3(21)

VALVE EXPERIMENTAL FLOW COEFFICIENT VS RATIO OF VALVE GEOMETRIC AREA TO ORIFICE GEOMETRIC AREA

L-No.	Valve Area/Orifice Area	L-No.	Valve Experimental Flow Coefficient
2663	0.00	2673	1.000
2664	0.20	2674	0.994
2665	0.40	2675	0.980
2666	0.60	2676	0.942
2667	0.80	2677	0.868
2668	1.00	2678	0.766

L-No.	Definition	Value
2662	Number of pairs in the table.	6

TABLE 25 THG4(31)

O-RING CROSS SECTION VS PINTLE DIAMETER
(Step Function)

L-No.	Pintle Diameter (in.)	L-No.	O-ring Cross Section (in.)
2684	0.14	2699	0.070
2685	0.45	2700	0.070
2686	0.45	2701	0.103
2687	0.85	2702	0.103
2688	0.85	2703	0.139
2689	1.65	2704	0.139
2690	1.65	2705	0.210
2691	4.70	2706	0.210
2692	4.70	2707	0.275
2693	300.00	2708	0.275

L-No.	Definition	Value
2683	Number of pairs in the table.	10

TABLE 26 THG5(46)

PRESSURE BALANCING CONSTANTS

L-No.	AV/AO	L-No.	Pressure Ratio Multiplier	L-No.	Pressure Modifier
2715	0.0	2730	0	2745	0
2716	0.1	2731	0	2746	0.07
2717	0.2	2732	0	2747	0.16
2718	0.3	2733	0	2748	0.26
2719	0.4	2734	0	2749	0.375
2720	0.5	2735	0	2750	0.5
2721	0.6	2736	0	2751	0.63
2722	0.7	2737	0	2752	0.735
2723	0.8	2738	0	2753	0.830
2724	0.9	2739	C	2754	0.940
2725	1.0	2740	0	2755	1.0

L-No.	Definition	Value
2714	Number of triplets in the table.	11

TABLE 27

THERMAL DIFFUSIVITY VS TEMPERATURE

L-No.	Temperature	L-No.	Thermal Diffusivity Tungsten	L-No.	Thermal Diffusivity Molybdenum	L-No.	Thermal Diffusivity Tantalum	L-No.	Thermal Diffusivity Other
2761	460	2771	0.082	2781	0.08	2791	0.0424	2801	0
2762	1,000	2772	0.0708	2782	0.0736	2792	0.0408	2802	0
2763	2,000	2773	0.056	2783	0.056	2793	0.0384	2803	0
2764	3,000	2774	0.0476	2784	0.0384	2794	0.0370	2804	0
2765	4,000	2775	0.0412	2785	0.028	2795	0.03596	2805	0
2766	5,000	2776	0.0396	2786	0.0214	2796	0.035	2806	0
2767	6,000	2777	0.0314	2787	0.0168	2797	0.035	2807	0
2768	7,000	2778	0.0284	2788	0.0128	2798	0.035	2808	0

L-No.	Thermal Diffusivity Silica Cloth	L-No.	Thermal Diffusivity Carbon Cloth	L-No.	Thermal Diffusivity Asbestos	L-No.	Thermal Diffusivity V-44
2811	0.000621	2821	0.000947	2831	0.0005	2841	0.0002145
2812	0.000621	2822	0.000947	2832	0.0005	2842	0.0002145
2813	0.000621	2823	0.000947	2833	0.0005	2843	0.0002145
2814	0.000621	2824	0.000947	2834	0.0005	2844	0.0002145
2815	0.000621	2825	0.000947	2835	0.0005	2845	0.0002145
2816	0.000621	2826	0.000947	2836	0.0005	2846	0.0002145
2817	0.000621	2827	0.000947	2837	0.0005	2847	0.0002145
2818	0.000621	2828	0.000947	2838	0.0005	2848	0.0002145

L-No.	Definition	Value
2760	Number of temperatures in the table.	8

TABLE 28 THG7(31)

O-RING GLAND LENGTH VS PINTLE DIAMETER

Line No.	Pintle Diameter (in.)	L-No.	O-ring Gland Length (in.)
2852	0.000	2867	0.507
2853	0.364	2868	0.507
2854	0.364	2869	0.545
2855	0.734	2870	0.545
2856	0.734	2871	0.604
2857	1.484	2872	0.604
2858	1.484	2873	0.724
2859	4.475	2874	0.724
2860	4.475	2875	0.779
2861	1,000.000	2876	0.779

L-No.	Definition	Value
2851	Number of pairs in the table.	10

TABLE 29 THG8(41)

RATIO OF FEEDBACK LENGTH TO MAXIMUM THEORETICAL STROKE
VS MAXIMUM THEORETICAL STROKE FOR ABLATIVE PINTLE

L-No.	Max Theoretical Stroke (in.)	L-No.	Feedback Length/Total Stroke
2883	0.0	2903	20.00
2884	0.1	2904	10.00
2885	0.2	2905	8.00
2886	0.3	2906	7.00
2887	0.4	2907	6.20
2888	0.5	2908	5.60
2889	0.7	2909	4.70
2890	0.9	2910	4.10
2891	1.1	2911	3.55
2892	1.3	2912	3.15
2893	1.5	2913	2.85
2894	1.7	2914	2.60
2895	2.0	2915	2.30
2896	2.5	2916	2.05
2897	3.5	2917	1.85
2898	5.5	2918	1.60
2899	6.5	2919	1.50
2900	8.0	2920	1.40
2901	12.0	2921	1.40

L-No.	Definition	Value
2882	Number of pairs in the table.	19

TABLE 30

THG9(41)

ABLATIVE PINTLE VALVE WEIGHT VS VALVE FLOW RATE (PER VALVE) FOR LEG, CLOSURE, OR PLENUM MOUNTED PINTLE VALVE

L-No.	Mean Valve Flow Rate (lb/sec)	L-No.	Valve Weight Log (lb)*
2924	1.0	2944	0.3617
2925	2.0	2945	0.5798
2926	3.0	2946	0.6990
2927	4.0	2947	0.7853
2928	6.0	2948	0.8633
2929	8.0	2949	0.9085
2930	10.0	2950	0.9494
2931	12.0	2951	0.9823
2932	16.0	2952	1.0492
2933	21.0	2953	1.1139
2934	26.0	2954	1.1761
2935	32.0	2955	1.2430
2936	38.0	2956	1.3010
2937	47.0	2957	1.3711
2938	56.0	2958	1.4314
2939	66.0	2959	1.4914
2940	82.0	2960	1.5694
2941	100.0	2961	1.6434
2942	140.0	2962	1.7839

L-No.	Definition	Value
2923	Number of pairs in the table.	19

TABLE 31

THG10(41)

PINTLE VALVE WEIGHT VS VALVE FLOW RATE (PER VALVE) FOR EXTERNALLY MOUNTED PINTLE VALVE

L-No.	Mean Valve Flow Rate (lb/sec)	L-No.	Valve Weight Log (lb)*
2965	1	2985	1.1139
2966	2	2986	1.2175
2967	4	2987	1.3222
2968	6	2988	1.3979
2969	8	2989	1.4624
2970	12	2990	1.5563
2971	16	2991	1.6232
2972	22	2992	1.6990
2973	28	2993	1.7559
2974	36	2994	1.8195
2975	44	2995	1.8692
2976	54	2996	1.9243
2977	64	2997	1.9685
2978	78	2998	2.0212
2979	91	2999	2.0607
2980	113	3000	2.1139
2981	140	3001	2.1644
2982	280	3002	2.4150

L-No.	Definition	Value
2964	Number of pairs in the table.	18

*Log_{10}

TABLE 32 THG11(41)

ROTATING CYLINDER VALVE WEIGHT VS VALVE FLOW RATE (PER VALVE)

L-No.	Mean Valve Flow Rate (lb/sec)	L-No.	Valve Weight Log (lb)*
3006	3.0	3026	0.8692
3007	5.0	3027	0.9542
3008	7.0	3028	1.0212
3009	10.0	3029	1.1139
3010	14.0	3030	1.2014
3011	18.0	3031	1.2695
3012	22.0	3032	1.3222
3013	28.0	3033	1.3802
3014	34.0	3034	1.4232
3015	44.0	3035	1.4771
3016	55.0	3036	1.5185
3017	70.0	3037	1.5682
3018	83.0	3038	1.6232
3019	102.0	3039	1.7160
3020	124.0	3040	1.8325
3021	140.0	3041	1.9243

L-No.	Definition	Value
3005	Number of pairs in the table.	16

TABLE 33 THG12(41)

JET PIPE VALVE WEIGHT VS VALVE FLOW RATE (PER VALVE)

L-No.	Mean Valve Flow Rate (lb/sec)	L-No.	Valve Weight Log (lb)*
3047	3.0	3067	1.7924
3048	5.0	3068	1.9191
3049	7.0	3069	2.0212
3050	10.0	3070	2.1461
3051	13.0	3071	2.2430
3052	16.0	3072	2.3222
3053	19.0	3073	2.3802
3054	22.0	3074	2.4346
3055	26.0	3075	2.4914
3056	34.0	3076	2.5682
3057	44.0	3077	2.6434
3058	56.0	3078	2.7160
3059	70.0	3079	2.7782
3060	82.0	3080	2.8195
3061	96.0	3081	2.8513
3062	110.0	3082	2.8893

L-No.	Definition	Value
3046	Number of pairs in the table.	16

*Log_{10}

TABLE 34 THG13(41)

PINTLE VALVE WEIGHT VS PINTLE DIAMETER FOR NONERODING, LEG MOUNTED PINTLE

L-No.	Pintle Diameter (in.)	L-No.	Valve Weight Log (lb)*
3088	0	3108	0.7404
3089	1	3109	1
3090	3	3110	1.4771
3091	4	3111	1.699
3092	5	3112	1.8865
3093	6	3113	2.0792
3094	7.5	3114	2.301
3095	10	3115	2.6435
3096	12	3116	2.8513
3097	16.45	3117	3.2305

L-No.	Definition	Value
3087	Number of pairs in the table.	10

TABLE 35 THG14(41)

PINTLE VALVE WEIGHT VS PINTLE DIAMETER FOR NONERODING, PLENUM MOUNTED PINTLE VALVE

L-No.	Pintle Diameter (in.)	L-No.	Valve Weight Log (lb)*
3129	0.1	3149	0.6021
3130	0.2	3150	0.6434
3131	0.4	3151	0.6990
3132	11.4	3152	2.9731

L-No.	Definition	Value
3128	Number of pairs in the table.	4

*Log_{10}

TABLE 36

PINTLE VALVE WEIGHT VS PINTLE DIAMETER FOR NONERODING, CLOSURE MOUNTED PINTLE VALVE

L-No.	Pintle Diameter (in.)	L-No.	Valve Weight Log (lb)*
3170	0	3190	0.7404
3171	1	3191	1
3172	3	3192	1.4771
3173	4	3193	1.699
3174	5	3194	1.8865
3175	6	3195	2.0792
3176	7.5	3196	2.301
3177	10	3197	2.6435
3178	12	3198	2.8513
3179	16.45	3199	3.2305

L-No.	Definition	Value
3169	Number of pairs in the table.	10

*Log $_{10}$

6. JET TAB PERFORMANCE INPUT

a. Jet Tab Optional Input

L-No.	Symbol	Definition	Value	Fortran Symbol
3990	t_i	Nominal time for complete insertion of tab	0 sec	TI
3991	θ	Exit cone divergence angle	10 deg	THETA
3992	μ_R	Axial bearing friction coefficient	0.005	FUR
3993	μ_T	Thrust bearing friction coefficient	0.005	FUT
3994	SPGR	Specific gravity of steel	7.85	SPGR
3995	3.4666	Empirical constant used to form K	3.4666	COEFJT
3996	$\Delta\beta$	Allowable torque box rotation	1.5 deg	DLTBTA
4000	d_1	Thickness used to form jet tab thickness	0 in.	D1
4001	d_2	Thickness used to form jet tab thickness	0 in.	D2
4002	d_3	Thickness used to form jet tab thickness	0 in.	D3
4003	d_4	Thickness used to form jet tab thickness	0 in.	D4
4004	d_5	Thickness used to form jet tab thickness	0 in.	D5
4005	SPGR (1)	Specific gravity used to form jet tab weight	19.3	SPG1
4006	SPGR (2)	Specific gravity used to form jet tab weight	1.9	SPG2
4007	SOGR (3)	Specific gravity used to form jet tab weight	1.75	SPG3

L-No.	Symbol	Definition	Value	Fortran Symbol
4008	SPGR (4)	Specific gravity used to form jet tab weight	7.85	SPG4
4009	SPGR (5)	Specific gravity used to form jet tab weight	1.82	SPG5

b. <u>Jet Tab Input Tables</u>--Additional jet tab input data are included in Tables 37 thru 40.

TABLE 37 TBLJ1(41)

INSTANTANEOUS TOTAL THRUST DECREMENT VS INSTANTANEOUS PITCH OR YAW THRUST DEFLECTION ANGLE

Thrust Deflection Angle (deg)		Total Thrust Decrement	
L-No.	δ	L-No.	AF/F
4011	0	4031	0
4012	0.2	4032	0.0011
4013	0.5	4033	0.0025
4014	1	4034	0.0055
4015	1.5	4035	0.0089
4016	2	4036	0.0128
4017	2.5	4037	0.0168
4018	3	4038	0.0213
4019	4	4039	0.0312
4020	5	4040	0.0420
4021	6	4041	0.0535
4022	7	4042	0.0659
4023	8	4043	0.0792
4024	9	4044	0.0935
4025	10	4045	0.1089
4026	12	4046	0.1415
4027	12.6	4047	0.1520

No. of points (N) in L-4010 = 17.
Maximum no. of points = 20

TABLE 38 TBLJ2(41)

RATIO OF THRUST DEFLECTION ANGLES VS TAB INSTANTANEOUS ANGULAR POSITION (PITCH OR YAW)

Ratio of Thrust Deflection Angles		Tab Angular Position (deg)	
L-No.	$\delta_{P,Y}/\delta_{max}$	L-No.	$\theta_{P,Y}$
4052	0	4072	0
4053	1	4073	60

No. of points (N) in L-4051 = 2.
Maximum no. of points = 20.

TABLE 39 TBLJ3 (41)

RATIO OF JET TAB UPSTREAM SURFACE AREA TO NOZZLE EXIT FLOW AREA VS MAXIMUM VECTOR ANGLE (PITCH OR YAW)

Maximum Vector Angle (deg)		Jet Tab Upstream Surface to Nozzle Exit Flow Area	
L-No.	δmax	L-No.	A_{JT}/A_N
4093	0	4113	0.0
4094	0.68	4114	0.01
4095	1.38	4115	0.02
4096	2.11	4116	0.03
4097	2.89	4117	0.04
4098	3.7	4118	0.05
4099	4.55	4119	0.06
4100	5 43	4120	0.07
4101	6.31	4121	0.08
4102	7.24	4122	0.09
4103	8.2	4123	0.10
4104	11.08	4124	0.13
4105	14.05	4125	0.16

No. of points (N) in L-4092 = 13.
Maximum no. of points = 20.

TABLE 40

EMPIRICAL CONSTANTS USED IN EQUATIONS

L-No.	Constant	L-No.	Constant
4133	0.042	4150	0.1133
4134	0.75	4151	60
4135	2	4152	3
4136	0.0361	4153	0.375
4137	0.165	4154	0.125
4138	0.8	4155	0.75
4139	2.083	4156	0.5
4140	0.755	4157	0.007
4141	0.000009	4158	1.45
4142	0.816	4159	0.816
4143	0.4855	4160	1.194
4144	0.506	4161	1.8695
4145	2.75	4162	6.6708
4146	0.566	4163	2.5464
4147	0.522	4164	1.5708
4148	1.05	4165	0.0262
4149	7	4166	0.0677
		4167	6.9814

7. ACTUATION AND ROLL INPUT

a. Actuation Routine Input for Hot Gas, Gimbal, Jet Tabs, Hinged Nozzle, and Fins

L-No.	Symbol	Definition	Value	Fortran Symbol
2060	--	TVC actuator type =0, pintle actuator =1, linear actuator =2, rotary actuator	1	TVCATP
2061	--	Actuator power system =0, system not specified =1, turbine =2, warm gas motor pump =3, electric motor pump =4, warm gas blowdown =5, electromechanical =6, self-pressurizing ADU =7, servopumps =8, electropneumatic	0	APS
2062	--	Roll system =0, not required =1, warm gas =2, cold gas =3, common roll and TVC generator =4, system not specified	1	ROLSYS

b. Actuation Optional Input for Hot Gas, Gimbal, Jet Tabs, Hinged Nozzle and Fins

L-No.	Symbol	Definition	Value	Fortran Symbol
5550	CSTAR	TVC generator characteristic velocity	3,724 ft/sec	CSTAR
5551	GAMMA	TVC generator specific heat ratio	1.279	GAMMA

L-No.	Symbol	Definition	Value	Fortran Symbol
5552	MBAR	TVC generator mean molecular weight	19.24	MBAR
5553	PGEN	TVC generator pressure	1,000 psi	PGEN
5554	PSU	TVC hydraulic supply pressure	3,000 psi	PSU
5555	RHOG	TVC generator gas density	0.000463 lb/cu in.	RHOG
5556	TGEN	TVC generator gas temperature	2,245°R	TGEN
5570	CSTARR	Roll generator characteristic velocity	3,724 ft/sec	CSTARR
5571	GAMMAR	Roll generator specific heat ratio	1.279	GAMMAR
5572	MBARR	Roll generator mean molecular weight	19.24	MBARR
5573	PRGEN	Roll generator pressure	1,000 psi	PRGEN
5574	RHOGR	Roll generator gas density	0.000463 lb/cu in.	RHOGR
5575	TGR	Roll generator gas temperature	2,245°R	TGR
5576	PRESRI	Cold gas initial tank pressure	6,000 psi	PRESRI
5577	PRESRR	Cold gas regulated pressure	750 psi	PRESRR
5578	PRESRF	Cold gas minimum tank pressure	900 psi	PRESRF
5579	NUMTHR	Number of dual nozzle thruster units	2	XUMTHR
5580	TEMRI	Cold gas initial temperature	530°R	TEMRI
5581		Roll moment arm multiplier	0.95	XMRMLT

c. Actuation Input Tables--Additional actuation input data are included in Tables 41 thru 66.

TABLE 41

GAS GENERATOR MASS FRACTION VS GAS HORSEPOWER

Horsepower		Mass Fraction at Chamber Pressure 700*		1,000*		2,000*		3,000*	
L-No.		L-No.		L-No.		L-No.		L-No.	
4225	0	4245	0	4265	0	4285	0	4305	0
4226	25	4246	0.4	4266	0.35	4286	0.305	4306	0.275
4227	40	4247	0.51	4267	0.45	4287	0.390	4307	0.353
4228	50	4248	0.555	4268	0.49	4288	0.422	4308	0.384
4229	75	4249	0.626	4269	0.565	4289	0.475	4309	0.430
4230	100	4250	0.675	4270	0.61	4290	0.508	4310	0.460
4231	125	4251	0.713	4271	0.64	4291	0.531	4311	0.479
4232	150	4252	0.737	4272	0.661	4292	0.548	4312	0.490
4233	175	4253	0.755	4273	0.675	4293	0.560	4313	0.496
4234	200	4254	0.767	4274	0.686	4294	0.570	4314	0.503
4235	250	4255	0.785	4275	0.703	4295	0.585	4315	0.511
4236	300	4256	0.798	4276	0.714	4296	0.595	4316	0.519
4237	350	4257	0.806	4277	0.722	4297	0.603	4317	0.523
4238	400	4258	0.814	4278	0.726	4298	0.606	4318	0.525
4239	500	4259	0.820	4279	0.730	4299	0.610	4319	0.530
4240	800	4260	0.820	4280	0.730	4300	0.610	4320	0.530

*Chamber Pressure (psi)

L-No.	Description		Value
4220	No. of table values per column	=	16
4221	Chamber pressure 1	=	700
4222	Chamber pressure 2	=	1,000
4223	Chamber pressure 3	=	2,000
4224	Chamber pressure 4	=	3,000

Maximum no. of points = 20

TABLE 42 ATBL2(41)

WEIGHT OF SERVOPUMP VS PUMP FLOW

L-No.	Servopump Flow (cu in./sec)	L-No.	Servopump Weight (lb)
4326	0.0	4346	2.0
4327	25.0	4347	6.0
4328	75.0	4348	14.7
4329	125.0	4349	22.6
4330	150.0	4350	26.9
4331	175.0	4351	31.0
4332	200.0	4352	36.0
4333	225.0	4353	40.8
4334	250.0	4354	45.5
4335	275.0	4355	50.6
4336	300.0	4356	56.0
4337	325.0	4357	61.8
4338	350.0	4358	67.1
4339	375.0	4359	73.0
4340	400.0	4360	79.0
4341	425.0	4361	85.4
4342	450.0	4362	92.0

L-No.	Description	Value
4325	No. of points per column	= 17

Maximum no. of points = 20

TABLE 43

WEIGHT OF TURBINE AND GEARBOX VS HYDRAULIC HORSEPOWER OUTPUT

L-No.	Hydraulic Horsepower Output	L-No.	Turbine and Gearbox (lb)
4367	0	4387	2.00
4368	17	4388	2.00
4369	23	4389	10.00
4370	28	4390	15.00
4371	32	4391	17.50
4372	35	4392	20.00
4373	40	4393	23.00
4374	44	4394	25.20
4375	50	4395	28.00
4376	60	4396	31.50
4377	70	4397	34.00
4378	80	4398	36.00
4379	90	4399	37.50
4380	100	4400	39.00
4381	120	4401	40.73
4382	140	4402	42.50
4383	180	4403	45.00
4384	200	4404	46.00
4385	240	4405	47.25
4336	340	4406	50.00

L-No.	Description	Value
4366	No. of points per column	= 20

Maximum no. of points = 20

TABLE 44 ATBL4(41)

WEIGHT OF SERVOVALVE VS ACTUATOR FLOW

L-No.	Actuator Flow (cu in./sec)	L-No.	Servovalve Weight (lb)
4408	0.0	4428	0.22
4409	12.5	4429	0.48
4410	25.0	4430	0.6
4411	37.5	4431	0.7
4412	50.0	4432	0.9
4413	62.5	4433	1.2
4414	75.0	4434	1.5
4415	87.5	4435	1.9
4416	112.5	4436	2.7
4417	150.0	4437	4.2
4418	185.0	4438	5.7
4419	230.0	4439	8.0
4420	265.0	4440	10.0
4421	310.0	4441	12.7
4422	345.0	4442	15.2
4423	370.0	4443	17.1
4424	400.0	4444	19.9
4425	425.0	4445	22.4
4426	500.0	4446	34.0

L-No.	Description	Value
4407	No. of points per column =	19

Maximum no. of points = 20

TABLE 45

WEIGHT OF SERVOACTUATOR VS ACTUATOR ENERGY

L-No.	Actuator Energy Log (ft-lb)*	L-No.	Servoactuator Weight (lb)
4449	1.000	4469	0.5
4450	2.477	4470	2.2
4451	2.602	4471	2.9
4452	2.699	4472	3.1
4453	2,845	4473	4.0
4454	3.000	4474	5.2
4455	3.176	4475	7.4
4456	3.301	4476	9.4
4457	3.477	4477	13.1
4458	3.602	4478	16.8
4459	3.778	4479	22.7
4460	4.000	4480	32.4
4461	4.176	4481	42.1
4462	4.301	4482	50.0
4463	5.000	4483	258.0

L-No.	Description	Value
4448	No. of points per column =	15

Maximum no. of points = 20

*Log_{10}

TABLE 46

WALL THICKNESS OF STANDARD HYDRAULIC LINES
(STEP FUNCTION)

Pressure ≤											
2,400				3,400				4,200			
L-No.	ID (in.)	L-No.	Wall Thickness (in.)	L-No.	ID (in.)	L-No.	Wall Thickness (in.)	L-No.	ID (in.)	L-No.	Wall Thickness (in.)
4495	0	4515	0.016	4535	0	4555	0.016	4575	0	4595	0.016
4496	0.34	4516	0.02	4536	0.24	4556	0.028	4576	0.24	4596	0.028
4497	0.46	4517	0.028	4537	0.38	4557	0.035	4577	0.32	4597	0.0342
4498	0.56	4518	0.035	4538	0.54	4558	0.042	4578	0.44	4598	0.049
4499	0.8	4519	0.049	4539	0.65	4559	0.058	4579	0.65	4599	0.065
4500	1.2	4520	0.065	4540	0.76	4560	0.065	4580	0.87	4600	0.083
4501	1.37	4521	0.083	4541	1.0	4561	0.082	4581	0.96	4601	0.096
4502	1.64	4522	0.096	4542	1.2	4562	0.096	4582	1.1	4602	0.12
4503	1.81	4523	0.12	4543	1.3	4563	0.120	4583	1.27	4603	0.154
4504	2.5	4524	0.136	454	1.63	4564	0.134	4584	1.5	4604	0.188
4505	3.0	4525	0.136	4545	1.87	4565	0.156	4585	2.12	4605	0.22
				4546	2.2	4566	0.188	4586	3.0	4606	0.22
				4547	2.62	4567	0.22				
				4548	3	4568	0.22				

L-No.	Description	Value
4489	No. of points corresponding to 1st pressure	11
4490	No. of points corresponding to 2nd pressure	11
4491	No. of points corresponding to 3rd pressure	= 12
4492	1st pressure	= 2,400
4493	2nd pressure	= 3,400
4494	3rd pressure	4,200

Maximum no. of points = 20

TABLE 47 ATBL6B(41)

DIAMETER OF STANDARD HYDRAULIC LINES (IN.)

L-No.	Inside Line Diameter (calc)	L-No.	Outside Line Diameter (std)
4616	0.00	4636	0.13
4617	0.16	4637	0.18
4618	2.60	4638	3.20

L-No.	Description	Value
4615	No. of points per column	= 3

Maximum no. of points = 20

TABLE 48

VOLUME VS WEIGHT OF SELFPRESSURIZING RESERVOIR
(3,000 PSI) (50 TO 1 UNBALANCE RATIO)

L-No.	Volume of Reservoir (cu in.)	L-No.	Reservoir Weight (lb)
4657	0.0	4677	1.8
4658	12.5	4678	2.9
4659	20.0	4679	3.5
4660	32.5	4680	4.3
4661	50.0	4681	5.7
4662	75.0	4682	6.4
4663	100.0	4683	7.4
4664	120.0	4684	8.1
4665	150.0	4685	9.1
4666	180.0	4686	10.0
4667	230.0	4687	11.2
4668	250.0	4688	11.7
4669	300.0	4689	12.7
4670	350.0	4690	13.6
4671	1,025.0	4691	25.2

L-No.	Description	Value
4656	No. of points per column =	15

Maximum no. of points = 20

TABLE 49 ATBL8(41)

WEIGHT OF HYDRAULIC TEE FILTERS VS FLOW RATE
AT 3,000 PSI

L-No.	System Flow (cu in./sec)	L-No.	Hydraulic Filter Weight (lb)
4698	0	4718	0.00
4699	5	4719	0.25
4700	565	4720	21.90

L-No.	Description	Value
4697	No. of points per column	= 3

Maximum no. of points = 20

TABLE 50 ATBL9(41)

WEIGHT OF HYDRAULIC DISCONNECTS
VS OUTSIDE PIPE DIAMETER

L-No.	Outside Pipe Diameter (in.)	L-No.	Hydraulic Disconnect Weight (lb)
4739	0.000	4759	0.10
4740	0.250	4760	0.30
4741	0.375	4761	0.40
4742	0.500	4762	0.50
4743	0.625	4763	0.70
4744	0.750	4764	0.90
4745	1.000	4765	1.40
4746	1.250	4766	2.00
4747	1.500	4767	2.60
4748	1.750	4768	3.40
4749	2.250	4769	5.10
4750	2.500	4770	6.00
4751	2.750	4771	7.15
4752	3.000	4772	8.60
4753	3.250	4773	10.20
4754	3.500	4774	12.00
4755	4.000	4775	16.00

L-No.	Description	Value
4738	No. of points per column	= 17

Maximum no. of points = 20

TABLE 51 ATBL10(41)

DISPLACEMENT OF ROTARY ACTUATOR VS OUTPUT TORQUE

L-No.	Output Torque Log (in.-lb)*	L-No.	Displacement (cu in./rad)
4780	2.00	4800	0.20
4781	2.70	4801	0.37
4782	3.00	4802	0.40
4783	3.30	4803	0.70
4784	3.60	4804	1.35
4785	3.78	4805	2.10
4786	4.00	4806	3.90
4787	4.17	4807	6.10
4788	4.30	4808	8.20
4789	4.47	4809	12.60
4790	4.77	4810	21.00
4791	5.30	4811	80.00
4792	5.70	4812	200.00
4793	6.00	4813	400.00
4794	6.30	4814	780.00
4795	6.60	4815	1,480.00
4796	6.78	4816	2,140.00

L-No.	Description	Value
4779	No. of points per column	= 17

Maximum no. of points = 20

*Log_{10}

TABLE 52 ATBL11(41)

PUMP WEIGHT VS PUMP FLOW RATE
FOR VARIABLE DELIVERY PUMPS AT 3,000 TO 4,000 PSI

L-No.	Pump Flow Rate (cu in./sec)	L-No.	Pump Weight (lb)
4821	0.0	4841	0.5
4822	12.5	4842	0.5
4823	225.0	4843	28.5
4824	275.0	4844	36.0
4825	325.0	4845	44.5
4826	350.0	4846	48.8
4827	357.5	4847	50.5
4828	380.0	4848	55.0
4829	400.0	4849	59.5
4830	442.5	4850	70.0
4831	495.0	4851	85.0

L-No.	Description	Value
4820	No. of points per column =	11

Maximum no. of points = 20

TABLE 53 ATBL12(41)

WEIGHT OF ELECTRIC MOTOR PUMP
VS OUTPUT HORSEPOWER
(VARIABLE DELIVERY, DC DRIVEN)

L-No.	Output Horsepower	L-No.	Motor Pump Weight (lb)
4862	0	4882	1.0
4863	0.21	4883	1.0
4864	30	4884	145.0

L-No.	Description	Value
4861	No. of points per column	= 3

Maximum no. of points = 20

TABLE 54 ATBL13(41)

WEIGHT OF WARM GAS MOTOR PUMP VS HYDRAULIC HORSEPOWER OUTPUT (VARIABLE DELIVERY)

L-No.	Hydraulic Horsepower Output	L-No.	Motor Pump Weight (lb)
4903	0.0	4923	0.95
4904	6.0	4924	3.4
4905	11.0	4925	5.4
4906	16.0	4926	7.6
4907	21.0	4927	10.0
4908	25.0	4928	12.8
4909	30.0	4929	16.7

L-No.	Description	Value
4902	No. of points per column	= 7

Maximum no. of points = 20

TABLE 55 ATBL14(41)

WEIGHT OF WARM GAS RELIEF VALVE
VS GAS FLOW RATE

L-No.	Gas Flow Rate (lb/sec)	L-No.	Relief Valve Weight (lb)
4944	0.000	4964	0.25
4945	0.275	4965	0.25
4946	0.375	4966	2.50
4947	0.500	4967	3.80
4948	0.625	4968	4.90
4949	0.750	4969	5.90
4950	0.875	4970	6.80
4951	1.000	4971	7.60
4952	1.125	4972	8.40
4953	1.250	4973	9.10
4954	1.375	4974	9.70
4955	1.500	4975	10.40
4956	1.750	4976	10.95
4957	2.000	4977	12.60
4958	2.250	4978	13.60
4959	2.500	4979	14.60
4960	3.000	4980	16.50

L-No.	Description	Value
4943	No. of points per column =	17

Maximum no. of points = 20

TABLE 56 ATBL15(41)

WEIGHT VS VOLUME OF BLOWDOWN ACCUMULATOR AT 3,000 PSI

L-No.	Volume (cu in.)	L-No.	Weight (lb)
4985	0.0	5005	0.5
4986	35.0	5006	0.5
4987	200.0	5007	14.7
4988	300.0	5008	21.5
4989	400.0	5009	27.6
4990	500.0	5010	32.8
4991	550.0	5011	35.0
4992	600.0	5012	37.3
4993	650.0	5013	39.0
4994	700.0	5014	40.6
4995	750.0	5015	42.0
4996	850.0	5016	44.4
4997	950.0	5017	46.6
4998	1,050.0	5018	48.5
4999	1,100.0	5019	49.3

L-No.	Description	Value
4984	No. of points per column =	15

Maximum no. of points = 20

TABLE 57 ATBL16(41)

ROTARY ACTUATOR WEIGHT VS OUTPUT TORQUE

L-No.	Output Torque Log (in.-lb)*	L-No.	Weight (lb)
5026	2.000	5046	0.5
5027	3.000	5047	2.0
5028	3.301	5048	3.5
5029	3.477	5049	4.8
5030	3.699	5050	7.5
5031	3.845	5051	10.5
5032	4.000	5052	14.5
5033	4.176	5053	20.2
5034	4.301	5054	26.0
5035	4.477	5055	38.0
5036	4.602	5056	46.0
5037	4.699	5057	54.4
5038	5.398	5058	130.0

L-No.	Description	Value
5025	No. of points per column =	13

Maximum no. of points = 20

*Log_{10}
Servovalve not included

TABLE 58 ATBL17(41)

LINEAR ELECTROMECHANICAL ACTUATOR
WEIGHT VS OUTPUT HORSEPOWER

L-No.	Output Horsepower (Log)*	L-No.	Weight (lb)
5067	-4.000	5087	0.1
5068	-2.523	5088	1.1
5069	-2.301	5089	1.6
5070	-2.097	5090	2.1
5071	-2.000	5091	2.5
5072	-1.699	5092	4.1
5073	-1.398	5093	6.2
5074	-1.155	5094	8.2
5075	-1.000	5095	9.8
5076	-0.824	5096	12.0
5077	-0.602	5097	15.6
5078	-0.398	5098	20.0
5079	-0.097	5099	28.0
5080	0.301	5100	40.0
5081	0.700	5101	56.0
5082	1.000	5102	77.0

L-No.	Description	Value
5066	No. of points per column =	16

Maximum no. of points = 20

*Log_{10}

TABLE 59 ATBL18(41)

ROTARY ELECTROMECHANICAL ACTUATOR WEIGHT
VS OUTPUT HORSEPOWER

L-No.	Output Horsepower (Log)*	L-No.	Weight (lb)
5108	-4.000	5128	0.1
5109	-1.824	5129	2.40
5110	-1.700	5130	2.55
5111	-1.523	5131	2.95
5112	-1.398	5132	3.40
5113	-1.222	5133	4.20
5114	-1.046	5134	5.20
5115	-0.824	5135	6.90
5116	-0.602	5136	9.00
5117	-0.398	5137	11.40
5118	-0.155	5138	14.30
5119	0.000	5139	16.40
5120	0.176	5140	19.40
5121	0.301	5141	22.00
5122	0.845	5142	39.00

L-No.	Description	Value
5107	No. of points per column	= 15

Maximum no. of points = 20

*Log_{10}

TABLE 60

STANDARD TUBING WALL THICKNESS VS OUTSIDE DIAMETER

L-No.	OD (in.)	L-No.	Minimum Wall Thickness (in.)	L-No.	Wall Thickness (in.)	L-No.	Wall Thickness (in.)*	L-No.	Wall Thickness (in.)*
5148	0.25	5168	0.02	5188	0.028	5208	0.035	5228	0.042
5149	0.375	5169	0.02	5189	0.028	5209	0.035	5229	0.042
5150	0.5	5170	0.028	5190	0.035	5210	0.042	5230	0.049
5151	0.625	5171	0.028	5191	0.035	5211	0.042	5231	0.049
5152	0.75	5172	0.028	5192	0.035	5212	0.042	5232	0.049
5153	1	5173	0.035	5193	0.042	5213	0.049	5233	0.058
5154	1.25	5174	0.035	5194	0.042	5214	0.049	5234	0.058
5155	1.5	5175	0.035	5195	0.042	5215	0.049	5235	0.058
5156	1.625	5176	0.035	5196	0.042	5216	0.049	5236	0.058
5157	1.75	5177	0.035	5197	0.042	5217	0.049	5237	0.058
5158	2	5178	0.035	5198	0.049	5218	0.058	5238	0.065
5159	2.25	5179	0.035	5199	0.049	5219	0.058	5239	0.065
5160	2.5	5180	0.049	5200	0.058	5220	0.065	5240	0.083
5161	3	5181	0.049	5201	0.058	5221	0.065	5241	0.083
5162	4	5182	0.083	5202	0.095	5222	0.12	5242	0.188
5163	5	5183	0.148	5203	0.188	5223	0.188	5243	0.25
5164	6	5184	0.180	5204	0.219	5224	0.25	5244	0.281
5165	7	5185	0.25	5205	0.281	5225	0.281	5245	0.375
5166	8	5186	0.25	5206	0.281	5226	0.281	5246	0.375
5167	9	5187	0.25	5207	0.281	5227	0.281	5247	0.375

*Wall thicknesses bounded by the heavy vertical line are the maximums corresponding to the specified OD.

Locations having zeros are available but not utilized.

TABLE 60 (Cont) TBLI1(20, 10)

STANDARD TUBING WALL THICKNESS VS OUTSIDE DIAMETER

L-No.	Wall Thickness (in.)*	L-No.	Wall Thickness (in.)*	L-No.	Wall Thickness (in.)*	L-No.	Wall Thickness (in.)*	L-No.	Wall Thickness (in.)*
5248	0.049	5268	0.058	5288	0.065	5308	0.095	5328	0
5249	0.049	5269	0.058	5289	0.065	5309	0.095	5329	0
5250	0.058	5270	0.065	5290	0.083	5310	0.095	5330	0
5251	0.058	5271	0.065	5291	0.083	5311	0.095	5331	0
5252	0.058	5272	0.065	5292	0.095	5312	0.12	5332	0
5253	0.065	5273	0.083	5293	0.095	5313	0.12	5333	0
5254	0.065	5274	0.083	5294	0.095	5314	0.12	5334	0
5255	0.065	5275	0.083	5295	0.095	5315	0.12	5335	0
5256	0.065	5276	0.083	5296	0.095	5316	0.12	5336	0
5257	0.065	5277	0.083	5297	0.095	5317	0.12	5337	0
5258	0.083	5278	0.095	5298	0.12	5318	0.188	5338	0
5259	0.083	5279	0.095	5299	0.12	5319	0.188	5339	0
5260	0.095	5280	0.12	5300	0.188	5320	0	5340	0
5261	0.095	5281	0.12	5301	0.188	5321	0.219	5341	0
5262	0.219	5282	0	5302	0	5322	0	5342	0
5263	0	5283	0	5303	0	5323	0	5343	0
5264	0	5284	0	5304	0	5324	0	5344	0
5265	0	5285	0	5305	0	5325	0	5345	0
5266	0	5286	0	5306	0	5326	0	5346	0
5267	0	5287	0	5307	0	5327	0	5347	0

Maximum no. of points per column = 20

*Wall thicknesses bounded by the heavy line are the maximums corresponding to the specified OD

TABLE 61 TBLI2(41)

MASS FRACTION VS GAS HORSEPOWER

L-No.	Gas Horsepower	L-No.	Mass Fraction
5349	0.0	5369	0.050
5350	2.5	5370	0.050
5351	5.0	5371	0.130
5352	10.0	5372	0.210
5353	17.5	5373	0.290
5354	25.0	5374	0.359
5355	32.5	5375	0.410
5356	42.5	5376	0.462
5357	57.2	5377	0.520
5358	67.5	5378	0.549
5359	80.0	5379	0.580
5360	92.5	5380	0.600
5361	107.5	5381	0.620
5362	125.0	5382	0.640
5363	140.0	5383	0.660
5364	170.0	5384	0.674
5365	200.0	5385	0.690
5366	375.0	5386	0.74
5367	1,000	5387	0.91
5368	2,000.0	5388	0.91

L-No.	Description	Value
5348	No. of points per column =	20

Maximum no. of points = 20

TABLE 62

WEIGHT OF DISCONNECTS VS OUTSIDE DIAMETER OF TUBING

L-No.	Diameter (in.)	L-No.	Weight (lb)
5390	0.000	5410	0.250
5391	0.250	5411	0.250
5392	0.350	5412	0.335
5393	0.450	5413	0.450
5394	0.550	5414	0.580
5395	0.650	5415	0.740
5396	0.775	5416	0.975
5397	0.925	5417	1.310
5398	1.075	5418	1.695
5399	1.275	5419	2.250
5400	1.525	5420	3.000
5401	4.000	5421	3.000

L-No.	Description	Value
5389	No. of points per column =	12

Maximum no. of points = 20

TABLE 63 TBLI7(41)

WEIGHT OF INJECTORS VS EQUIVALENT FLOW OF WATER

L-No.	Equivalent Flow (lb/sec)	L-No.	Weight (lb)
5431	0.00	5451	0.600
5432	1.75	5452	0.600
5433	3.00	5453	1.050
5434	4.25	5454	1.400
5435	5.50	5455	1.710
5436	7.50	5456	2.110
5437	9.50	5457	2.450
5438	12.00	5458	2.800
5439	13.75	5459	3.000
5440	16.75	5460	3.300
5441	20.00	5461	3 600
5442	58.50	5462	6.630
5443	120.00	5463	16.0
5444	200.00	5464	27.4
5445	250.00	5465	27.4

L-No.	Description	Value
5430	No. of points per column	= 15

Maximum no. of points = 20

TABLE 64 TBLI9(41)

COLD GAS REGULATOR VALVE WEIGHT VS GAS FLOW

L-No.	Gas Flow Rate (lb/sec)	L-No.	Weight (lb)
5472	0	5492	0.4
5473	100	5493	0.4
5474	3,200	5494	10.0
5475	7,000	5495	10.0

L-No.	Description	Value
5471	No. of points per column	= 4

Maximum no. of points = 20

TABLE 65

COLD GAS NOZZLE WEIGHT VS NOZZLE FLOW

L-No.	Nozzle Flow (lb/sec)	L-No.	Weight (lb)
5591	0.00	5611	1.00
5592	0.28	5612	1.00
5593	3.20	5613	5.45

Closed center valve and Bowtie nozzles included

L-No.	Description	Value
5590	No. of Points per column =	3

Maximum No. of points = 20

TABLE 66 RTBL44(41)

COLD GAS REGULATOR WEIGHT VS SYSTEM FLOW RATE

L-No.	System Flow Rate (lb/sec)	L-No.	Weight (lb)
5632	0.00	5652	0.6
5633	0.4	5653	0.94
5634	1.4	5654	1.94
5635	1.8	5655	2.26
5636	2.2	5656	2.56
5637	2.6	5657	2.74
5638	3.0	5658	2.84

Relief valve integral

L-No.	Description	Value
5631	No. of points per column =	7

Maximum No. of points = 20

8. WEIGHT SUMMARY INPUT

a. Weight Summary Optional Input

L-No.	Symbol	Definition	Value	Fortran Symbol
5800	XLITVC	Center-of-gravity (LITVC)	0 in.*	XLITVC
5801	XHGTVC	Center-of-gravity (HGTVC)	0 in.*	XHGTVC
5802	XJTAB	Center-of-gravity (jet tabs)	0 in.*	XJTAB
5803	XMNACT	Center-of-gravity (movable nozzle actuation)	0 in.*	XMNACT
5804	XROLLC	Center-of-gravity (roll control system)	0 in.*	XROLLC
5805	XCTHR	Center-of-gravity (cooled throat system)	0 in.*	XCTHR
5806	CNBWM	Multiplier for the aft nozzle base weight	1.0	CNBWM
5807	ELPSRA	Ellipse ratio of the aft closure	1.4	ELPSRA

*These values are calculated if they are not input.

B. ERROR MESSAGES

1. NOZZLE

The following errors may occur in the nozzle design calculations.

An invalid specification has been made for nozzle type

An invalid specification has been made for TVC code

An invalid specification has been made for pivot center location

An invalid specification has been made for hot gas valve mounting code

An invalid specification has been made for throat type

An invalid specification has been made for exit configuration

An invalid specification has been made for case type

An invalid specification has been made for nozzle designator code

Insufficient input to determine throat area

Insufficient input to determine expansion ratio

Unable to converge in iteration for initial cone angle

Root not bounded in iteration for initial expansion ratio

Unable to converge in iteration for initial expansion ratio

Unable to converge in iteration for cone turnback angle

Root not bounded in iteration for initial cone angle

Insufficient input to determine action time

Insufficient input to determine chamber pressure

Insufficient input to determine case diameter

Percent submergence for this plenum configuration is to face of exit ring rather than face of flange

Insufficient input to determine contour exit cone

An invalid expansion ratio has been specified

Unable to converge in iteration for Mach number

An invalid specification has been made for throat type

Ejection load near zero or instantaneous chamber pressure greater than structural design pressure--use output cautiously

Unable to converge in iteration for nozzle inner limit angle

Input liner load per unit area incompatible with design--value calculated

Theoretical force amplification factor calculation inaccurate with this design, the factor is set to unity

Unable to make radius to outer liner edge less than the mean spherical radius

Unable to converge in iteration for step change in angle in iteration loops

Flexiable seal is elastomer shear stress critical

Unable to converge in iteration for radial height of section

Calculated seal deflection inaccurate. To bring into accurate range reduce elastomer layer thickness or increase total seal thickness

Unable to close gimbal ring design within constraints--height increased

Gimbal ring is at constrained limit size

Unable to converge in iteration for actual Y-moment of inertia of gimbal ring section

Unable to converge in iteration for actual X-moment of inertia of gimbal ring section

Rings are solid

Input radius to inside of flang incompatible with design

Flange adapter added to locate flange at specified radius. Percent submergence is calculated to junction of adapter and primary structure.

Exit cone exceeds m: :imum diameter limit

Unable to converge in iteration for honeycomb strucure

Extrapolation has occurred in the following table. The argument was xxx
Standard tubing wall thickness vs outside diameter

Extrapolation has occurred in the following table. The argument was xxx
Standard tubing wall thickness vs outside diameter

Extrapolation has occurred in the following table. The argument was xxx
Cold gas regulator valve weight vs gas flow

Solution for minor radius of toroidal coolant tank is imaginary

Solution for minor radius of toroidal gas tank is imaginary

Unable to converge in iteration for Mach number at station 11

Material not found in strength versus temperature table for pintle nozzle

Error in strength versus temperature table for pintle nozzle

Invalid designator no. for pintle design

Insufficient input for pintle design

Unable to converge in iteration for pintle nozzle throa: area

TLfD was increased to prevent interference in pintle design

LSM , LAPA and TKCSIN were increased to prevent interference during actuation in pintle design

Unable to converge in iteration for stroke calculation

GTYPE = 2. Both ATMXA and ATMNA were not input ATMAXA and ATMINA were used. Stroke calculation may be in error

RBH, ratio of width to height of gimbal ring, violates limits. Limit value used

Contour exit is invalid in given envelope cone exit used

2. TORQUE

The following errors may occur in the torque calculations.

An incorrect nozzle type has been specified for torque. The value was xxx

No result was found for the cubic solution for shock angle in external aerodynamic equations

Iteration for the maximum deflection angle for attached shock required for external aerodynamic torque did not converge

Iteration for Mach number required for external aerodynamic torque did not converge

3. LIQUID INJECTION

a. Performance

The following errors may occur in the LITVC performance calculations.

An invalid injectant type has been specified. Freon 113 was used

The specified injectant will not meet the maximum TVC requirements

The specified number of valves per quadrant is not compatible with the performance curves The number of valves used was xxx

The average thrust deflection angle is too small for the alternate method.

An advanced injectant system is not available. See note below.

Extrapolation has occurred in the following table. The argument was xxx
Freon force ration vs flow ratio performance

Extrapolation has occurred in the following table. The argument was xxx
N_2O_4 force ratio vs flow ratio performance

Extrapolation has occurred in the following table. The argument was xxx
Duty cycle time points

The integration interval has been specified as zero. 0.05 has been substituted

Extrapolation has occurred in the following table. The argument was xxx
Freon and N_2H_4-UDMH force ratio vs secondary specific impulse performance

Extrapolation has occurred in the following table. The argument was xxx
N_2O_4 force ratio vs secondary specific impulse performance

Extrapolation has occurred in the following table. The argument was xxx
SR $(CLO_4)_2$ plus H_2O force ratio vs secondary specific impulse performance

Extrapolation has occurred in the following table. The argument was xxx
PB $(CLO_4)_2$ plus H_2O force ratio vs secondary specific impulse performance

Extrapolation has occurred in the following table. The argument was xxx
SR $(CLO_4)_2$ plus C_2H_5OH force ratio vs secondary specific impulse performance

Extrapolation has occurred in the following table. The argument was xxx
SR $(CLO_4)_2$ plus CH_3OH force ratio vs secondary specific impulse performance

b. Actuation

The following errors may occur in the LITVC actuation calculations

The injectant cannot be used as the hydraulic fluid

Extrapolation has occurred in the following table. The argument was xxx
Weight of injectors vs equivalent flow of water

Extrapolation has occurred in the following table. The argument was xxx
Standard tubing wall thickness vs outside diameter

Spherical tanks will not fit in the specified envelope

The solution for the toroidal tank radius is imaginary

Toroidal tanks will not fit in the specified envelope.

Extrapolation has occurred in the following table. The argument was xxx
Weight vs volume of blowdown accumulator

Extrapolation has occurred in the following table. The argument was xxx
Mass fraction vs gas horsepower

Extrapolation has occurred in the following table. The argument was xxx
Weight of warm gas relief valve vs gas flow rate

Extrapolation has occurred in the following table. The argument was xxx
Weight of hydraulic tee filters vs flow rate

Extrapolation has occurred in the following table. The argument was xxx
Weight of disconnects vs outside diameter of tubing

Extrapolation has occurred in the following table. The argument was xxx
Cold gas regulator valve weight vs gas flow

An invalid system has been specified. An attempt will be made to select a system

No valid system could be selected

An invalid system has been specified. No corrective action can be taken

Extrapolation has occurred in the following table. The argument was xxx
Volume vs weight of self-pressurizing reservoir

Extrapolation has occurred in the following table. The argument was xxx
Weight of electric motor pump vs output horsepower

Extrapolation has occurred in the following table. The argument was xxx
Weight of warm gas motor pump vs hydraulic horsepower output

4. HOT GAS

The following errors may occur in the hot gas calculations

Extrapolation has occurred in the following table. The argument was xxx
Valve experimental flow coefficient vs ratio of valve geometric area to orifice geometric area

Extrapolation has occurred in the following table The argument was xxx
Ratio of pintle diameter to valve orifice diameter vs valve orifice diameter for noneroding valve

Extrapolation has occurred in the following table. The argument was xxx
Ratio of pintle diameter to valve orifice diameter vs valve orifice diameter for ablative valve

Iteration for ratio of valve flow area to nozzle throat area vs time did not converge

Extrapolation has occurred in the following table. The argument was xxx
Duty cycle time table

Unable to integrate for burning time extension resulting from valve operation

Unable to integrate for total vehicle vacuum thrust impulse from stage ignition to termination

Unable to integrate for total weight of injected gases

Extrapolation has occurred in the following
table. The argument was xxx
Thermal diffusivity vs temperature

Extrapolation has occurred in the following
table. The argument was xxx
Pintle valve weight vs pintle diameter for
noneroding, plenum mounted pintle valve

Iteration for ratio of valve sonic flow area to
primary nozzle flow area (performance calculated)
failed.

Iteration for geometric orifice flow area did not
converge

Extrapolation has occurred in the following
table. The argument was xxx
Pressure balancing constants

Extrapolation has occurred in the following
table. The argument was xxx
O-ring cross section vs pintle diameter

Extrapolation has occurred in the following
table. The argument was xxx
O-ring gland length vs pintle diameter

Extrapolation has occurred in the following
table. The argument was xxx
Ratio of feedback length to maximum theoretical stroke vs maximum theoretical stroke
for ablative pintle

Unable to integrate for weight of propellant gases
injected in either the pitch or yaw plane

Extrapolation has occurred in the following
table. The argument was xxx
Valve experimental flow coefficient vs
ratio of valve geometric area to orifice
geometric area

5. JET TABS

The following errors may occur in the jet tabs performance calculations

Extrapolation has occurred in the following
table. The argument was xxx
Total thrust decrement vs pitch or yaw deflection angle

Extrapolation has occurred in the following
table. The argument was xxx
Ratio of thrust deflection angles vs
tab angular position

Extrapolation has occurred in the following
table. The argument was xxx
Ratio of jet tab upstream surface area to
nozzle exit flow area vs maximum vector angle

An incorrect nozzle type has been specified
for jet tabs. The value specified was xxx

6. ACTUATION

The following errors may occur in the actuation calculations

TMC & TVC hydraulic supply pressures not equal

Roll system not required

Extrapolation has occurred in the following
table. The argument was xxx
Wall thickness of standard hydraulic lines

Extrapolation has occurred in the following
table. The argument was xxx
Diameter of standard hydraulic lines

Cold gas minimum tank pressure low--
use 1.2 * cold gas regulated pressure as
minimum

TVC & roll generated ballistics not equal program
uses TVC generator for sizing roll system

TVC & TMC system not reqd - common roll &
TVC generator not applicable

Extrapolation has occurred in the following
table. The argument was xxx
Weight of servopump vs pump flow

Extrapolation has occurred in the following
table. The argument was xxx
Displacement of rotary actuator

Extrapolation has occurred in the following
table. The argument was xxx
Gas generator mass fraction vs gas horsepower

Extrapolation has occurred in the following table. The argument was xxx

Pump weight vs pump flow rate for variable delivery pumps

Extrapolation has occurred in the following table. The argument was xxx

Weight of turbine and gearbox vs hydraulic horsepower output

Extrapolation has occurred in the following table. The argument was xxx

Weight of servoactuator vs actuator energy

Extrapolation has occurred in the following table. The argument was xxx

Rotary actuator weight vs output torque

Extrapolation has occurred in the following table. The argument was xxx

Volume vs weight of self-pressurizing reservoir

Extrapolation has occurred in the following table. The argument was xxx

Weight of hydraulic tee filters vs flow rate

Extrapolation has occurred in the following table. The argument was xxx

Weight of hydraulic disconnects vs outside pipe diameter

Extrapolation has occurred in the following table. The argument was xxx

Weight of electric motor pump vs output horsepower

Extrapolation has occurred in the following table. The argument was xxx

Weight of warm gas motor pump vs hydraulic horsepower output

Extrapolation has occurred in the following table. The argument was xxx

Weight of warm gas relief valve vs gas flow rate

Extrapolation has occurred in the following table. The argument was xxx

Weight vs volume of blowdown accumulator

Extrapolation has occurred in the following
table. The argument was xxx
Rotary electromechanical actuator weight vs
output horsepower

Extrapolation has occurred in the following
table. The argument was xxx
Linear electromechanical actuator weight vs
output horsepower

Extrapolation has occurred in the following
table. The argument was xxx
Cold gas nozzle weight vs nozzle flow

Extrapolation has occurred in the following
table. The argument was xxx
Cold gas regulator weight vs system flow rate

7. WEIGHT SUMMARY

The following error may occur in the weight summary calculation

Error Code	Line* Number	Subroutine Name	Description	
1	XXX	TP200	$X_i = X_{i-1}$ for a call to the integration subroutine TP221	
2	XXX	TP200	The calculated weight was zero. CG and moments will not be calculated for this line number.	
1	XXX	TP201	ELO < -A	ELO and ELI are the axial distances from the center of an ellipse with a major axis half length of A.
2	XXX	TP201	ELO > A	
3	XXX	TP201	ELI < -A	
4	XXX	TP201	ELI > A	
5	XXX	TP201	A = O	
6	XXX	TP201	The calculated weight was zero. CG and moments will not be calculated for this line number.	

*Line numbers used by subroutines TP200 and TP201 are working areas only. They will be in the range of 194 to 200.

C. SAMPLE INPUT

Included in this section and the next, Sample Output, are four test cases that execute all of the Hardware Section.

INPUT SHEET
FORM TC NO 230

NAME | DATE | P

2 1 1 1 1

L 7046 +6

L 7100 +0 +20 +54 +54 +60 +60.6

L 7400 +220000 +220000 +220000 +64000 +64000 +64000

L 7600 +220000 +220000 +220000 +64000 +64000 +64000

L 7700 +880 +880 +880 +256 +256 +256

L 0 +5 +6 +2

L 5 +2

L 21 +4 +65

L 34 +6260 +1.18 +5200 +16 +14

L 40 +1

L 42 +234916.5 +1025.98 +10.98889

L 46 +18960.195 +54.04 +8.9909

L 50 +699.246

L 92 +184.296 +150.788

L 732 +10

INPUT SHEET
FORM TC NO 220

NAME DATE PAGE

L1076 +.6

T HARDWARE TEST CASE NO. 1

INPUT SHEET
FORM TC NO 210

NAME

DATE

PAGE

```
   2               1 1
L7046 +3
L7100 +0 +35 +70
L7400 +56800 +56800 +56800
L7600 +56800 +56800 +56800
L7700 +225 +225 +225
L0 +1 +1
L4 +1 +2 +1 +1
L11 +72.806
L14 +25
L16 +52.56
L18 +24.8 +70 +450 +3 +65.5
T HARDWARE TEST CASE NO. 2
```

INPUT SHEET
FORM TC NO 290

NAME | DATE | PAGE

```
    2                1   1
L7046  +3
L7100  +0  +35  +70
L7400  +56800  +56800  +56800
L7600  +56800  +56800  +56800
L7700  +225  +225  +225
L0  +1  +2
L3  +1  +1  +2  +1  +1
L11  +72.806
L14  +2
L16  +52.56
L18  +24.8  +70  +450  +3  +65.5
L2000  +4  +1.9  +1  +2  +3  +3  +2  +2  +3
T HARDWARE TEST NO. 3
```

INPUT SHEET
FORM TC NO 290

NAME | DATE | PAGE

```
   2               1         1
L7046 +3
L7100 +0 +35 +70
L7400 +56800 +56800 +56800
L7600 +56800 +56800 +56800
L7700 +225 +225 +225
L0 +1 +3
L4 +1 +2 +1 +1
L11 +72.806
L14 +25
L16 +52.56
L18 +24.8 +70 +450 +3 +65.5
T HARDWARE TEST CASE NO. 4
```

D. SAMPLE OUTPUT

This section contains the printout of the program resulting from the input specified in the previous section, Sample Input.

The printout of the first test case contains all of the resulting printout of that case.

In the printout of test cases 2, 3 and 4, the printout of the duty cycle and nozzle have been deleted since an example may be found in the first test case.

Test Case No.	Portion of Hardware Section
1	Duty Cycle Print
1	Nozzle
1	Torque
1	Actuation
1	Weight Summary
2	Liquid Injection Performance
2	Liquid Injection Actuation
3	Hot Gas
4	Jet Tabs

CTIAP INPUT

```
L7046 +6
L710C +0 +20 +54 +54 +60 +60.6
L740C +220000 +220000 +220000 +64000 +64000 +64000
L760C +220000 +220000 +220000 +64000 +64000 +64000
L770C +880 +880 +880 +256 +256 +256
L0 +5 +6 +2
L5 +2
L21 +4 +65
L34 +6260 +1.16 +5200 +16 +14
L40 +1
L42 +234916.5 +1025.96 +10.58889
L46 +16960.195 +54.04 +8.9909
L50 +699.246
L92 +164.296 +150.788
L732 +10
L1076 +.6
T HARDWARE TEST CASE NO. 1
```

HARDWARE TEST CASE NO. 1

---- TVC DUTY CYCLE CHARACTERISTICS ---- PAGE 1

						VALUE IF NOT INPUT
L7000	I-DEL	DELIVERED MOTOR TOTAL IMPULSE		0.12310865E 08	LB-SEC	NOTE A
L7001	I-VAC	VACUUM MOTOR TOTAL IMPULSE		0.12310865E 08	LB-SEC	NOTE A
L7005	ISPVACH	VACUUM SPECIFIC IMPULSE AT EXP RAT		250.000	LBF-SEC/LBM	NOTE A
L7030	STG TIME	MOTOR ACTION TIME		60.60	SEC	NOTE A
L7031	STG VAC THRUST	MOTOR AVERAGE VACUUM THRUST		0.20314956E 06	LB	NOTE A
L7034	EXP RAT	NOZZLE AVERAGE EXPANSION RATIO		0.0	---	NOTE B
L7035	AT	NOZZLE AVERAGE THROAT AREA		0.0	IN**2	NOTE B
L7036	GAMMA	ISENTROPIC EXPONENT		0.0	---	NOTE B
L7037	PCA	MOTOR AVERAGE CHAMBER PRESSURE		0.0	PSIA	NOTE B
L7038	C-STAR	CHARACTERISTIC VELOCITY OF EXHAUST GAS		0.0	FT/SEC	NOTE B
L7002	X-E	BODY STATION OF ESTIMATED GIMBAL POINT		1000.00	FT	1000.,NT.G
L7003	X-NF	BODY STATION OF NOZZLE FLANGE FACE		1000.00	FT	1000.,NT.G
L7028	CASE DIA	MOTOR DIAMETER		0.0	IN	NOTE B
L7004	D-DESIGN	DESIGN VECTOR ANGLE		0.001	DEG	.001,NT. G
L7014	D-PMAX	MAX PITCH VECTOR ANGLE		0.0	DEG	NOTE A
L7020	D-YMAX	MAX YAW VECTOR ANGLE		0.0	DEG	NOTE A
L7011	T-NP	TIME OF D-PMAX		0.0	SEC	NOTE A
L7017	T-NY	TIME OF D-YMAX		0.0	SEC	NOTE A
L7012	ETA-P	RATIO OF DEL THRUST TO VAC THRUST AT T-NP		1.000	---	NOTE A
L7018	ETA-Y	RATIO OF DEL THRUST TO VAC THRUST AT T-NY		1.000	---	NOTE A
L7010	I-DDOTP	PITCH DEFLECTION RATE INTEGRAL	REQUIRED ONLY FOR	90.000	DEG	90.
L7016	I-DDOTY	YAW DEFLECTION RATE INTEGRAL	BLOWDOWN SYSTEMS	90.000	DEG	90.
L7007	SLEW	CONTROL SYSTEM REQUIRED SLEW RATE		20.000	DEG/SEC	20.
L7096	ROLL TORQUE	MAXIMUM DISTURBING ROLL TORQUE	REQUIRED IF ROLL SYSTEM	0.0	IN-LB	
L7069	I-ROLL	INTEGRAL OF ROLL TORQUE	IS REQUESTED, L2070 =1.	0.0	FT-LB-SEC	
L7090	M1	MACH NUMBER AT AFT END OF SKIRT OR CASE		3.00	---	NOTE E
L7091	P1	STATIC PRES AT AFT END OF SKIRT OR CASE		0.0	PSIA	NOTE E
L7092	X1	BODY STATION, AFT END OF SKIRT OR CASE		1000.00	FT	NOTE E
L7093	X0	BODY STATION, FWD END OF SKIRT		0.0	FT	NOTE E,F
L7094	SIGMA	FLARE ANGLE OF SKIRT		0.0	DEG	NOTE E,F

----------THE FOLLOWING NOTES APPLY IF REQUIREMENTS SECTION (TRAJECTORY SIMULATION) IS NOT ENTERED----------

A ---- IF USER DOES NOT INPUT VALUES, VALUES WILL BE CALCULATED FROM THE TABLES ON THE NEXT PAGE

B ---- NOT REQUIRED HERE IF INPUT IN THE NOZZLE SECTION

C ---- MANDATORY INPUT FOR ALL

D ---- MINIMUM OF THREE POINTS REQUIRED. IF ANY TRACE IS DISCONTINUOUS, AT LEAST THREE POINTS MUST BE INPUT ON EACH SIDE OF EACH DISCONTINUITY WITH DOUBLE TIME ENTRIES AT THE DISCONTINUITY

E ---- REQUIRED IF EXTERNAL AEROTORQUE IS TO BE CALCULATED (NOTE- M1 MUST BE GREATER THAN 1.0)

F ---- REQUIRED ONLY IF SKIRT IS FLARED

G ---- IF VECTOR ANGLE IS TO BE CORRECTED FOR DIFFERENCE BETWEEN ESTIMATED AND ACTUAL GIMBAL POINTS, SET D-DESIGN = 1.E-3 AND INPUT BEST ESTIMATES OF X-E AND X-NF

HARDWARE TEST CASE NO. 1

---- TVC DUTY CYCLE CHARACTERISTICS ---- PAGE 2 ---- NUMBER OF DUTY CYCLE DATA POINTS (L7046) = 6 (NOTES C,D)

TIME,SEC L7100-99 NOTES C,D	PITCH ANGLE,DEG L7200-99 NOTES C,D	YAW ANGLE,DEG L7300-99 NOTES C,D	CEL. THRUST,LB L7400-99 NOTES C,D	VEHICLE C.G.,FT L7500-99 NOTES C,D	VAC. THRUST,LB L7600-99 NOTES C,D	WEIGHT FLOW,LB/SEC L7700-99 NOTES C,D
0.0	0.0	0.0	220000.0	0.0	220000.0	880.000
20.000	0.0	0.0	220000.0	0.0	220000.0	880.000
54.000	0.0	0.0	220000.0	0.0	220000.0	880.000
54.000	0.0	0.0	64000.0	0.0	64000.0	256.000
60.000	0.0	0.0	64000.0	0.0	64000.0	256.000
80.000	0.0	0.0	64000.0	0.0	64000.0	256.000
INTEGRAL =	0.0	0.0	0.12310865E 08	----------	0.12310865E 08	0.49243457E 05 (PROP. WT.)
AVERAGE =	0.0	0.0	0.20314956E 06	0.0	0.20314956E 06	812.598
INTEGRAL OF VECTOR SUM		0.0				
AVERAGE VECTOR ANGLE		0.0				

HARDWARE TEST CASE NO. 1

NOZZLE DESIGN SUMMARY (PAGE 1) WEIGHT AND GEOMETRY

NOZZLE DESIGNATOR CODE		562
INTEGRAL MOVABLE NOZZLE	TYPE	5
FLEXIBLE SEAL THRUST VECTOR CONTROL	TVC CODE	6
PIVOT CENTER FORWARD OF SEAL	PCL CODE	2
PLASTIC THROAT	THROAT CODE	3
CONTOURED EXIT	EXIT CODE	2

---WEIGHT SUMMARY---

TMC ASSEMBLY + TOTAL NOZZLE	1499.64	LB
TMC ASSEMBLY	438.55	LB
TOTAL NOZZLE	1061.08	LB
INSULATION	507.24	LB
STRUCTURE	553.84	LB
MOVABLE SECTION	692.05	LB
FIXED SECTION	369.03	LB

---GEOMETRY---

L	12	DTINT	THROAT DIAMETER, INITIAL	16.423	IN
L	13	ATINT	THROAT AREA, INITIAL	211.834	IN**2
L	10	DTAVG	THROAT DIAMETER, AVERAGE	17.367	IN
L	11	ATAVG	THROAT AREA, AVERAGE	236.875	IN**2
L	14	THETAI	MAXIMUM EXIT HALF ANGLE (INITIAL DIVERGENCE ANGLE)	23.000	DEG
L	15	DELTH	THETAI MINUS ANGLE AT EXIT PLANE (TURNBACK ANGLE)	10.000	DEG
		ALFEQ	ANGLE OF LINE FROM THROAT TO EXIT (EQUIVALENT CONE ANGLE)	18.303	DEG
L	17	EPSINT	EXPANSION RATIO, INITIAL	6.824	-
L	18	EPSAVG	EXPANSION RATIO, AVERAGE	6.103	-
L	29	RRATD	DOWNSTREAM EXTERNAL THROAT RADIUS RATIO	0.600	-
L	32	RNOZB2	RADIUS TO INSIDE OF INSULATION AT FLANGE	16.510	IN
L	23	XNF	MISSILE STATION AT NOZZLE FLANGE	1000.000	FT
L	31	THETAC	INLET ANGLE	45.00	DEG
L	26	XFRAT	FLANGE LOCATION, X/LNZ	0.3000	-
L	16	LNZ	LENGTH, THROAT TO EXIT	40.025	IN
		XOVL	LENGTH, OVERALL	52.873	IN
		LNOZ	LENGTH, EXTERNAL	28.018	IN
		XNS	LENGTH, ENTRY TIP TO THROAT	12.847	IN
		XNTF	LENGTH, ENTRY TIP TO FLANGE FACE	24.855	IN
		GAMFN	RADIUS OF ARC USED TO APPROXIMATE CONTOUR	264.109	IN
		XNOP	AXIAL COORDINATE OF ARC CENTER FROM THROAT	105.121	IN
		YNOP	RADIAL COORDINATE OF ARC CENTER FROM AXIS	234.510	IN
		RVECT	OUTER RADIUS OF EXIT AT MAX. VECTOR	26.151	IN
		RNMAX	MAX RADIUS OF ANY PART OF NOZZLE IN VECTORED POSITION	26.151	IN

VALUES PRECEDED BY AN L NUMBER CAN BE FIXED BY THE USER BY INPUT OF THE DESIRED VALUE IN THAT LOCATION

HARDWARE TEST CASE NO. 1

NOZZLE DESIGN SUMMARY (PAGE 2) PERFORMANCE AND DESIGN CONTROL VALUES

		RSPL	RADIUS OF SPLITLINE BETWEEN FIXED AND MOVABLE SECTIONS	19.249	IN

---PERFORMANCE AND PROPELLANT---

L	421	XDOT6	THROAT EROSION RATE	4.2776	MILS/SEC
L	39	BLOWCO	BLOWING COEFFICIENT (EROSION PARAMETER)	0.1083	
		CFVI	IDEAL VACUUM THRUST COEFFICIENT AT EPSAVG,XLAMN	1.6579	-
		ALFEFF	EFFECTIVE DIVERGENCE HALF ANGLE	14.9267	DEG
		XLAMN	DIVERGENCE CORRECTION (LAMBDA)	0.9831	-
L	35	GAM	ISENTROPIC EXPONENT (GAMMA) OF EXHAUST GAS	1.1800	-
L	34	TEC	CHAMBER TEMPERATURE	6260.0	DEG R
L	36	CSTAR	CHARACTERISTIC VELOCITY	5200.0	FT/SEC
L	37	ALUM	PER CENT ALUMINUM IN PROPELLANT	16.00	-
L	38	BINDER	PER CENT BINDER IN PROPELLANT	14.00	-
L	7	TPBND	BINDER TYPE CODE FOR BETA CALC. (1-PBAA,PBAN, 2-CTPB)	1.	-

---DESIGN CONTROL VALUES---

L	20	PC	AVERAGE CHAMBER PRESSURE	375.26	PSIA
L	27	MEOP	STRUCTURAL DESIGN PRESSURE (MEOP)	1109.34	PSIA
L	28	PA	AMBIENT PRESSURE	0.0	PSIA
L	19	TA	TIME OF MOTOR OPERATION	6.60	SEC
L	21	DELMXI	DESIGN THRUST VECTOR ANGLE	4.00	DEG

TWO THRUST LEVEL MOTOR SPECIFIED---ABOVE VALUES ARE SUSTAIN PHASE VALUES
BOOST PHASE VALUES FOLLOW

L	51	BTA	BOOST ACTION TIME	54.00	SEC
L	52	BPCA	BOOST AVERAGE PRESSURE	924.45	PSI
L	53	BXDOT	BOOST THROAT EROSION RATE	8.48	MILS/SEC
L	54	CTA	COAST TIME (MOTOR SHUT DOWN)	0.0	SEC
		DIABTA	BOOST AVERAGE THROAT DIAMETER	16.881	IN
		BEPSAV	BOOST AVERAGE EXPANSION RATIO	6.459	-
		BCFVI	BOOST THRUST COEFFICIENT	1.6666	-
		BALFEF	BOOST EFFECTIVE HALF ANGLE	14.89	DEG
		BLAMN	LAMBDA CORRESPONDING TO BALFEF	0.98322	-
L	33	FEJDES	DESIGN NOZZLE EJECTION LOAD	358861.	LB
		SIDFLD	DESIGN SIDE LOAD	27178.	LB

HARDWARE TEST CASE NO. 1

NOZZLE DESIGN SUMMARY (PAGE 5) SPECIAL TABLES

LOADS ON MOVABLE PART OF NOZZLE

	FEJCT	FAMB	FNS	DTHRST	TIME	PAT	EEX
MAXIMUM	299052.	0.	361953.	-62901.	0.0	924.45	5.82
MINIMUM	33641.	0.	48717.	-15075.	60.60	132.27	6.08

DTHRST= MOVABLE EXIT THRUST LOAD,LB   FAMB= AMBIENT PRESSURE LOAD,   LB
FNS   = NOSE OR SPLITLIN-   LOAD,LB   TIME= TIME,   SEC
EEX   = EXPANSION RATIO AT TIME, --   PAT = CHAMBER PRESSURE AT TIME,PSI
FEJCT = FAMB + FNS + DTHRST (NET EJECTION LOAD),LB

HARDWARE TEST CASE NO. 1

NOZZLE INSULATION DESIGN (PAGE 1) INSULATION STATION TABLE

BDST	INST	EPS	X	R	M	PS	FSE	MOD	XDOT	TLE	FSC	TLC	TLV	TL	TBU	A	TBM	TB	TTOT	L	NO.
1		4.567	12.008	17.548	0.0	0.0	1.50	1.00	0.0	0.0	1.50	0.549	0.275	0.824	0.214		0.0	0.214	1.033	L	126
2UP		4.043	-5.925	15.510	0.0	0.0	1.50	1.00	0.0	0.0	1.50	0.549	0.275	0.824	0.214	0	0.0	0.214	1.038	L	180
2DN		3.868	-5.892	16.150	0.0	0.0	1.50	1.00	0.0	0.0	1.50	0.665	0.333	0.999	0.060	0	0.0	0.060	1.059	L	198
3UP		3.719	-12.847	15.336	0.0	0.0	1.50	1.00	0.0	0.490	1.50	0.665	0.578	1.734	0.060		0.0	0.060	1.794	L	252
4DN(NOSE)		3.719	-12.847	15.836	0.0	0.0	1.50	1.00	0.0	0.490	1.00	0.466	0.245	1.201	0.214		0.0	0.214	1.415	L	342
5UP		1.860	-8.212	11.200	0.0	0.0	1.50	1.00	0.0	0.745	1.00	0.466	0.373	1.584	0.214	1	0.0	0.214	1.798	L	360
5DN		1.860	-8.212	11.200	0.0	0.0	1.50	1.00	0.0	0.384	1.25	0.0	1.000	1.384	0.179	1	0.236	0.415	1.798	L	378
6(THROAT)		1.000	0.0	8.212	0.0	0.0	1.50	1.00	0.0	0.486	1.25	0.0	1.000	1.486	0.179		0.0	0.179	1.554	L	414
7UP		1.098	1.925	8.603	0.0	0.0	1.50	1.00	0.0	0.255	1.25	0.0	1.000	1.255	0.179	1	0.030	0.208	1.463	L	450
7DN		1.098	1.925	8.603	0.0	0.0	1.25	1.00	0.0	0.495	1.00	0.630	0.124	1.249	0.214	1	0.0	0.214	1.463	L	468
	7.1	1.734	7.204	10.813	0.0	0.0	1.25	1.00	0.0	0.256	1.00	0.590	0.064	0.910	0.214		0.0	0.214	1.124	L	486
	7.2	2.370	12.012	12.642	0.0	0.0	1.25	1.00	0.0	0.148	1.00	0.553	0.037	0.738	0.214		0.0	0.214	0.952	L	504
8UP		3.006	16.364	14.238	0.0	0.0	1.25	1.00	0.0	0.119	1.00	0.530	0.030	0.680	0.214	1	0.0	0.214	0.893	L	522
8DN		3.006	16.364	14.238	0.0	0.0	1.25	1.00	0.0	0.119	1.00	0.530	0.030	0.680	0.214	1	0.0	0.214	0.893	L	540
	8.1	3.643	20.492	15.672	0.0	0.0	1.25	1.00	0.0	0.111	1.00	0.515	0.028	0.654	0.214		0.0	0.214	0.868	L	558
	8.2	4.279	24.479	16.986	0.0	0.0	1.25	1.00	0.0	0.107	1.00	0.492	0.027	0.626	0.214		0.0	0.214	0.839	L	576
14UP		4.915	28.385	18.205	0.0	0.0	1.25	1.00	0.0	0.100	1.00	0.461	0.025	0.586	0.214	0	0.0	0.214	0.800	L	594
14DN		4.915	28.385	18.205	0.0	0.0	1.25	1.00	0.0	0.100	1.00	0.461	0.025	0.586	0.214	0	0.0	0.214	0.800	L	612
	14.1	5.551	32.254	19.343	0.0	0.0	1.25	1.00	0.0	0.090	1.00	0.418	0.023	0.531	0.214		0.0	0.214	0.745	L	630
	14.2	6.188	36.122	20.426	0.0	0.0	1.25	1.00	0.0	0.079	1.00	0.374	0.020	0.472	0.214		0.0	0.214	0.686	L	648
15(EXIT)		6.824	40.025	21.451	0.0	0.0	1.25	1.00	0.0	0.066	1.00	0.340	0.017	0.423	0.214		0.0	0.214	0.637	L	666
	SL	2.370	12.008	12.640	0.0	0.0	1.25	1.00	0.0	0.148	1.00	0.553	0.037	0.738	0.214		0.0	0.214	0.952	L	684

DEFINITION OF SYMBOLS

BDST	BOUNDARY STATION SYMBOL	FSC	FACTOR OF SAFETY,CHAR
INST	INTERMEDIATE STATION SYMBOL	TLC	CHARRED LINER THICKNESS (IN)
EPS	EXPANSION RATIO AT STATION	TLV	VIRGIN LINER THICKNESS AT END OF FIRING (IN)
X	AXIAL DISTANCE DOWNSTREAM OF THROAT (IN)	TL	TOTAL LINER THICKNESS AT IGNITION, TLE + TLC + TLV,(IN)
R	RADIUS FROM AXIS (IN)	TBU	REQUIRED BACKUP INSULATION THICKNESS (IN)
M	MACH NUMBER	A	BOUNDARY MATCH FLAG (1 REQUIRES MATCHING OF TTOT ON EACH SIDE)
PS	STATIC PRESSURE	TBM	EXTRA BACKUP NECESSARY FOR MATCH OF TTOT (IN)
FSE	FACTOR OF SAFETY, EROSION	TB	TOTAL BACKUP THICKNESS, TBU + TBM, (IN)
MOD	EROSION RATE MULTIPLIER	TTOT	TOTAL OF LINER AND BACKUP THICKNESSES, TL + TB, (IN)
XDOT	EROSION RATE OF LINER (MILS PER SEC)	LNO	L NUMBER OF EPS , NUMBERS ARE SEQUENTIAL FROM LEFT TO RIGHT
TLE	ERODED LINER THICKNESS (IN)	SL	SPLITLINE,FLANGE,OR INJECTOR STATION IN EXIT

SOME VALUES IN TABLE ARE NOT OPTIONAL INPUT,SEE DIAGRAM IN USERS MANUAL FOR THIS NOZZLE DESIGNATOR

NOTE-- IF XDOT IS INPUT AT THROAT,XDOT AT EACH STATION WILL CHANGE BY THE RATIO (XDOT THROAT INPUT/XDOT THROAT CALCULATED) EXCEPT AT STATIONS WHERE XDOT IS ALSO INPUT. USE MOD TO CHANGE THROAT XDOT ONLY.

HARDWARE TEST CASE NO. 1

NOZZLE INSULATION DESIGN (PAGE 14) INSULATION STATION TABLE FOR BOOST AND SUSTAIN CONDITIONS

		BOOST						SUSTAIN					
BDST	INST	EPS	M	PS	XDOT	TLE	TLC	EPS	M	PS	XDOT	TLE	TLC
1		5.253	0.114	917.42	0.0	0.0	0.399	7.641	0.078	373.92	0.0	0.0	0.150
2UP		5.253	0.114	917.42	0.0	0.0	0.399	7.641	0.078	373.92	0.0	0.0	0.150
2DN		4.836	0.124	916.15	0.0	0.0	0.488	7.035	0.085	373.68	0.0	0.0	0.178
3UP		4.753	0.126	915.85	8.61	0.465	0.488	6.914	0.086	373.62	3.86	0.025	0.178
4DN(NOSE)		4.753	0.126	915.85	8.61	0.465	0.378	6.914	0.086	373.62	3.86	0.025	0.088
5UP		1.882	0.335	865.50	13.14	0.709	0.378	2.738	0.223	364.47	5.45	0.036	0.088
5DN		1.882	0.335	865.50	6.76	0.365	0.0	2.738	0.223	364.47	2.81	0.019	0.0
6(THROAT)		1.000	1.000	525.45	8.48	0.458	0.0	1.000	1.000	213.30	4.28	0.028	0.0
7UP		1.695	1.888	149.08	4.55	0.246	0.0	2.466	2.219	33.87	1.37	0.009	0.0
7DN		1.695	1.888	149.08	8.84	0.477	0.518	2.466	2.219	33.87	2.67	0.018	0.112
	7.1	2.678	2.286	73.91	4.59	0.248	0.497	3.896	2.570	17.61	1.20	0.008	0.093
	7.2	.661	2.525	47.31	2.61	0.141	0.465	5.325	2.794	11.47	1.02	0.007	0.088
8UP		.644	2.697	34.05	2.11	0.114	0.449	6.755	2.958	8.34	0.86	0.006	0.082
8DN		4.644	2.697	34.05	2.11	0.114	0.449	6.755	2.958	8.34	0.86	0.006	0.082
	8.1	5.626	2.832	26.24	1.97	0.107	0.442	8.184	3.088	6.46	0.70	0.005	0.073
	8.2	6.609	2.943	21.14	1.90	0.103	0.431	9.614	3.195	5.23	0.59	0.004	0.062
14UP		7.592	3.037	17.59	1.79	0.097	0.417	11.043	3.287	4.37	0.44	0.003	0.045
14DN		7.592	3.037	17.59	1.79	0.097	0.417	11.043	3.287	4.37	0.44	0.003	0.045
	14.1	8.575	3.119	14.98	1.64	0.088	0.398	12.473	3.368	3.73	0.27	0.002	0.020
	14.2	9.557	3.191	12.99	1.45	0.078	0.374	13.902	3.439	3.24	0.07	0.000	0.000
15(EXIT)		10.540	3.256	11.43	1.23	0.066	0.340	15.332	3.503	2.86	0.0	0.0	0.0
	SL	3.660	2.525	47.33	2.61	0.141	0.465	5.324	2.793	11.48	1.02	0.007	0.088

NOTE-- SEE PAGE 1 FOR A DEFINITION OF THE SYMBOLS

HARDWARE TEST CASE NO. 1

NOZZLE INSULATION DESIGN (PAGE 2) MATERIALS,WEIGHT SUMMARY, AND THROAT INSERT GEOMETRY
MATERIAL IDENTIFICATION AND WEIGHT OF INSULATION SECTIONS BETWEEN STATIONS

SECTION	LINER MATERIAL CODE	LINER WEIGHT LB	BACKUP MATERIAL CODE	BACKUP WEIGHT LB	TOTAL SECTION WEIGHT	L NUMBER OF LINER CODE
1-2UP	9	71.70	3	25.65	97.35	L 702
2DN-3UP	7	72.57	3	0.0	72.57	L 707
4DN-5UP	7	42.33	3	38.17	80.49	L 727
5DN-7UP	10	48.34	3	13.71	62.05	L 732
7DN-8UP	7	53.56	3	17.61	71.17	L 742
8DN-14UP	7	43.07	3	19.14	62.21	L 747
14DN-15	7	39.27	3	22.12	61.40	L 752

MATERIAL CODES ARE IDENTIFIED IN INSULATION MATERIALS TABLE AT BOTTOM OF PAGE

INSULATION MATERIALS

CODE	NAME	VIRGIN DENSITY (LB/IN**3)	CHAR DENSITY (LB/IN**3)	L NUMBER OF VIR. DENS.
1	GRAPHITE CLOTH PHENOLIC	0.0521	0.0376	L 757
2	SILICA CLOTH PHENOLIC	0.0632	0.0509	L 759
3	GLASS CLOTH PHENOLIC	0.0660	0.0538	L 761
4	HIGH DENSITY GRAPHITE	0.0686	0.0	L 763
5	PYROLYTIC GRAPHITE	0.0777	0.0	L 765
6	TUNGSTEN	0.6980	0.0	L 767
7	CARBON CLOTH PHENOLIC	0.0521	0.0376	L 769
8	ASBESTOS CLOTH PHENOLIC	0.0637	0.0509	L 771
9	FILLED BUNA RUBBER	0.0464	0.0230	L 773
10	CARBON-CARBON COMPOSITE	0.0506	0.0	L 775
11	POROUS TUNGSTEN	0.5584	0.0	L 777
12	PYROLYTIC GRAPHITE COATING	0.0777	0.0	L 779
13		0.0	0.0	L 781
14		0.0	0.0	L 783
15		0.0	0.0	L 785

L NUMBERS IN ALL THREE TABLES ARE CONSECUTIVE FROM LEFT TO RIGHT

HARDWARE TEST CASE NO. 1

NOZZLE STRUCTURAL DESIGN (PAGE 1) RINGS, SHELLS, AND SPECIAL STATIONS

STRUCTURAL RINGS

	SAFETY FACTOR	MATERIAL CODE	X TO CENTROID (IN)	R TO CENTROID (IN)	AXIAL LENGTH (IN)	RADIAL THICKNESS (IN)	WEIGHT (LB)	MINIMUM THICKNESS (IN)	L NUMBER OF SAFETY FACTOR
FLANGE	1.25	2	12.231	17.752	0.447	2.484	35.01	0.30	L 787
MOVABLE EXTENSION	1.25	2	-2.784	13.300	11.218	0.203	53.95	0.20	L 819
EXIT RING	1.25	2	17.597	16.961	1.075	1.139	36.91	0.20	L 827
FORWARD END RING	1.25	2	-5.428	13.660	3.075	1.352	100.99	0.20	L 843
AFT END RING	1.25	2	-4.372	14.455	2.628	1.266	85.55	0.20	L 851
FLEXIBLE SEAL SHIMS	1.25	11							L 875

STRUCTURAL SHELLS

SHELL (STATION-TO-STATION)	SAFETY FACTOR	MATERIAL CODE	X,UPSTREAM END (IN)	X,DOWNSTREAM END (IN)	THICKNESS UPSTREAM (IN)	THICKNESS DOWNSTREAM (IN)	WEIGHT (LB)	MINIMUM THICKNESS (IN)	L NUMBER OF SAFETY FACTOR
WS 1-2	1.25	2	12.008	-5.925	0.300	0.297	151.12	0.100	L 883
WS 7-12	1.25	2	1.925	18.369	0.100	0.100	41.53	0.100	L 915
WS12-15	1.25	6	18.369	40.025	0.194	0.050	19.19	0.050	L 923

SPECIAL STRUCTURAL STATIONS

STATION	X FROM THROAT (IN)	RADIUS TO LINER SURFACE (IN)	L NUMBER OF X
12	18.369	14.944	L 933

---OPTIONAL EXIT RING INPUT---

L 108	XACT	AXIAL DISTANCE FROM THROAT TO POINT OF ACTUATOR ATTACHMENT	13.454	IN
L 109	RACT	RADIAL DISTANCE TO POINT OF ACTUATOR ATTACHMENT	17.752	IN

MATERIAL CODES REFER TO STRUCTURAL MATERIALS TABLE ON NEXT PAGE

HARDWARE TEST CASE NO. 1

NOZZLE STRUCTURAL DESIGN (PAGE 2) STRUCTURAL MATERIALS

STRUCTURAL MATERIALS

CODE	NAME	DENSITY (LB/IN**3)	MODULUS (PSI)	DESIGN STRENGTH (PSI)	COMPRESSIVE YIELD STRENGTH (PSI)	POISSONS RATIO	L NUMBER OF DENSITY
1	MARAGING STEEL	0.2870	27000000.	215000.	200000.	0.30	L 935
2	180,000 ULTIMATE STEEL	0.2830	29000000.	180000.	179000.	0.30	L 940
3	90,000 ULTIMATE STEEL	0.2830	29000000.	90000.	70000.	0.30	L 945
4	6AL-4V TITANIUM	0.1600	16500000.	160000.	155000.	0.31	L 950
5	7075-T652 ALUMINUM	0.1010	10500000.	70000.	63000.	0.33	L 955
6	STRUCTURAL FIBERGLASS	0.0700	4000000.	60000.	45000.	0.25	L 960
7	BERYLLIUM	0.0660	42500000.	40000.	30000.	0.30	L 965
8	MOLYBDENUM	0.3680	47000000.	90000.	90000.	0.30	L 970
9	COLUMBIUM	0.3100	15000000.	40000.	40000.	0.39	L 975
10	304 STAINLESS STEEL	0.2860	28000000.	125000.	55000.	0.30	L 980
11	17-7 PH STEEL	0.2760	29000000.	170000.	160000.	0.30	L 985
12	WASPALOY	0.2960	31000000.	180000.	112000.	0.31	L 990
13		0.0	0.	0.	0.	0.0	L 995
14		0.0	0.	0.	0.	0.0	L 1000
15		0.0	0.	0.	0.	0.0	L 1005
16		0.0	0.	0.	0.	0.0	L 1010
17		0.0	0.	0.	0.	0.0	L 1015
18	FLEXIBLE SEAL ELASTOMER	0.0470	24.(SHEAR)	500.(SHEAR)	---------------	0.4998	L 1020

(L NUMBERS ARE CONSECUTIVE FROM LEFT TO RIGHT)

HONEYCOMB MATERIALS

19	HONEYCOMB CORE	0.00266	L 1061

20 FLAG USED TO DESIGNATE HONEYCOMB IN STRUCTURAL SHELL TABLE ON PREVIOUS PAGE (IF SHELL CODE IS 20, HONEYCOMB IS USED)

	CODE(ABOVE TABLE)	L NUMBER OF FACING CODE STORAGE LOCATION
INNER HONEYCOMB FACING	10.	L 1063
OUTER HONEYCOMB FACING	10.	L 1064

HARDWARE TEST CASE NO. 1

FLEXIBLE SEAL DESIGN (PAGE 1 OF 2)

---WEIGHT---					
			TOTAL WEIGHT OF SEAL ASSEMBLY	216.13	LB
			WEIGHT OF CORE LAMINATE	29.58	LB
			WEIGHT OF METAL IN CORE	27.14	LB
			WEIGHT OF CORE ELASTOMER	2.45	LB
			WEIGHT OF FORWARD END RING	100.99	LB
			WEIGHT OF AFT END RING	85.55	LB
---GEOMETRY---					
		ASEAL	SPHERICAL RADIUS OF MEAN SHIM	19.249	IN
		BETAM	ANGLE TO CENTER OF MEAN SHIM	46.949	DEG
L	97	SHANG	SHEAR ANGLE- NULL	10.000	DEG
		PSHANG	PLUS VECTOR	49.685	DEG
		CMSHNG	MINUS VECTOR	-40.23[illegible]	DEG
L	95	BETA1	INNER DEFINING ANGLE OF MEAN SHIM	45.[illegible]	DEG
L	96	BETA2	OUTER DEFINING ANGLE OF MEAN SHIM	48[illegible]	DEG
		RIN	INNER SPHERICAL RADIUS	18.[illegible]	IN
		ROT	OUTER SPHERICAL RADIUS	1[illegible]	IN
L	94	HGT	RADIAL HEIGHT OF CORE	1.300	IN
		CHD	CHORD OF MEAN SHIM	1.309	IN
L	100	RHT	RATIO OF HEIGHT TO CHORD	1.000	-
		TR	THICKNESS OF ELASTOMER LAYERS	0.025	IN
		TRNO	NUMBER OF ELASTOMER LAYERS	18.000	-
L	99	TM	THICKNESS OF METAL SHIMS	0.050	IN
		TMNO	NUMBER OF METAL SHIMS	17.000	-
L	98	TMTR	RATIO OF TM TO TR	2.000	-
		XPIV	PIVOT LOCATION FROM THROAT	-18.033	IN
			SEAL END POINT COORDINATES (ORIGIN AT PIVOT)		
		XII		13.101	IN
		RII		13.202	IN
		XIO		12.107	IN
		RIO		14.119	IN
		XOI		14.121	IN
		ROI		14.020	IN
		XOO		13.200	IN
		ROO		14.890	IN

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                          HARDWARE TEST CASE NO. 1

                       FLEXIBLE SEAL DESIGN (PAGE 2)

   ---CHARACTERISTICS---
          FEJDES    DESIGN LOAD FOR SEAL DESIGN                                              343629.        LB
          DELZ      AXIAL DEFLECTION AT DESIGN LOAD                                            0.053        IN

          STRSC     CALCULATED SHIM STRESS                                                   105309.        PSI
          STRST     CALCULATED SHIM STRESS MULTIPLIED BY FSB                                 131637.        PSI
          CYS       COMPRESSIVE YIELD STRENGTH OF SHIM                                       160000.        PSI
          STRSB     CALCULATED CRITICAL BUCKLING STRE _ OF DESIGN                            131600.        PSI
          FEF       FIT OF FINITE ELEMENT STRESS                                              93450.        PSI

 L    79  OFLG      MATCHING FLAG                                                                1.         -
                      (0- CYS AND STRSB MUST EXCEED STRST)
                      (1- LESSER OF CYS AND STRSB MUST EQUAL STRSTUNLESS DESIGN ELASTOMER SHEAR OR STRAIN CRITICAL)

          SSS       ELASTOMER SHEAR STRESS                                                      428.        PSI
 L 1022   SSLM      ELASTOMER SHEAR STRENGTH                                                    500.        PSI
          STRAIN    ELASTOMER SHEAR STRAIN                                                     2.885        -
 L 2410   CN321     INPUT STRAIN LIMIT                                                         3.000        -

          KSEAL     SEAL TORQUE SPRING RATE                                                      0.         IN-LB/DEG
          TSEAL     SEAL SPRING TORQUE AT MAXIMUM VECTOR ANGLE                                   0.         IN-LB
          TBOOT     FLEXIBLE SEAL BOOT TORQUE                                                    0.         IN-LB


   ---INPUT DESIGN VALUES---

 L    71  RMXB      RADIAL LIMIT LINE                                                         13.198        IN
 L    72  XIM       AXIAL  LIMIT LINE                                                          6.922        IN

 L    73  ANGN      ITERATION START ANGLE                                                     45.219        DEG
 L    74  ANGM      ITERATION LIMIT ANGLE                                                      0.0          DEG
 L    76  DALL      ITERATION CLOSURE ANGLE                                                    0.003        DEG
 L    77  DANN      ITERATION STEP ANGLE                                                       3.000        DEG

 L   101  FSB       SHIM STRESS FACTOR OF SAFETY                                               1.250        -
 L   102  FSH       ELASTOMER SHEAR FACTOR OF SAFETY                                           1.250        -

 L    75  ELMS      MINIMUM GAP LENGTH                       (APPLIES TO TYPES 6 AND 7 ONLY)   0.0          IN
 L   103  EMSLIN    THICKNESS OF INSULATED SPLITLINE STRUCTURE (DOES NOT APPLY TO TYPE 5 NOZZLES) 0.0       IN
 L   104  BTK       BOOT THICKNESS                                                             0.200        IN

 L   876            SHIM MATERIAL CODE (REFER TO STRUCTURAL MATERIAL TABLE)                   11.           -
 L   852            END RING MATERIAL CODE                                                     2.           -

 L 1021   GR        ELASTOMER SHEAR MODULUS                                                   24.0          PSI
 L 1024   MUR       ELASTOMER POISSONS RATIO                                                   0.4998       -
 L 1020   DENP      ELASTOMER DENSITY                                                          0.0470       LB/IN**3
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HARDWARE TEST CASE NO. 1

COMPRESSIVE YIELD STRENGTH (PSI) AS A FUNCTION OF TEMPERATURE (DEG R)

		TEMPERATURE (DEG R)								L-NO OF CODE COLUMN
CODE	MATERIAL	540.	860.	1260.	1660.	2060.	3460.	4960.	6460.	L 1486
1	GRAPHITE CLOTH PHENOLIC	10000	8500.	5000.	3700.	3300.	0.	0.	0.	L 1495
6	TUNGSTEN	100000.	100000.	76000.	55500.	40500.	14000.	5000.	100.	L 1504
0		0.	0.	0.	0.	0.	0.	0.	0.	L 1513
0		0.	0.	0.	0.	0.	0.	0.	0.	L 1522
11	17-7 PH STEEL	160000.	150000.	114900.	35500.	0.	0.	0.	0.	L 1531
12	WASPALOY	112000.	108000.	106000.	104000.	78000.	0.	0.	0.	L 1540
0		0.	0.	0.	0.	0.	0.	0.	0.	L 1549
0		0.	0.	0.	0.	0.	0.	0.	0.	L 1558

L-NOS ARE CONSECUTIVE FROM LEFT TO RIGHT (CODE, 540, 360 ETC.)

THE FIRST FOUR LINES OF THE TABLE ARE RESERVED FOR INSULATION MATERIALS. THE LAST FOUR LINES ARE FOR STRUCTURAL MATERIALS

REFER TO THE CORRECT TABLE FOR THE MATERIAL CODE

HARDWARE TEST CASE NO. 1

PINTLE NOZZLE DESIGN PARAMETERS (PAGE 1)

L	40	PNOZ	CONTROL - AN INPUT OF 1 CAUSES THE PROGRAM TO DESIGN A PINTLE NOZZLE	1	-
L	41	PTYPE	PINTLE TYPE (1 = SOLID TUNGSTEN; 2 = TUNGSTEN SHELL; 3 = ABLATIVE SLEEVE)	3	-

---AERODYNAMIC THROAT SIZING---

L	42	FMAX	MAXIMUM THRUST LEVEL	234916.50	LB
L	43	PCMAX	CHAMBER PRESSURE AT FMAX	1025.98	PSIA
L	44	EPSMAX	EXPANSION RATIO AT FMAX	10.989	-
L	45	ATMINA	AERODYNAMIC THROAT AREA AT FMAX	131.548	IN**2
		CFVMAX	IDEAL VACUUM THRUST COEFFICIENT AT FMAX	1.7406	-
L	46	FMIN	MINIMUM NON-ZERO THRUST LEVEL	18960.20	LB
L	47	PCMIN	CHAMBER PRESSURE AT FMIN	54.04	PSIA
L	48	EPSMIN	EXPANSION RATIO AT FMIN	8.991	-
L	49	ATMAXA	AERODYNAMIC THROAT AREA AT FMIN	204.684	IN**2
		CFVMIN	IDEAL VACUUM THRUST COEFFICIENT AT FMIN	1.7141	-
		FB	AVERAGE BOOST THRUST LEVEL	219999.81	LB
		BPCA	CHAMBER PRESSURE AT FB	924.45	PSIA
		EPSB	EXPANSION RATIO AT FB	10.540	-
		ATBA	AERODYNAMIC THROAT AREA AT FB	137.146	IN**2
		CFVB	IDEAL VACUUM THRUST COEFFICIENT AT FB	1.7352	-
		BTA	BOOST ACTION TIME	54.00	SEC
		FS	AVERAGE SUSTAIN THRUST LEVEL	63948.51	LB
		PC	CHAMBER PRESSURE AT FS	375.26	PSIA
		EPSS	EXPANSION RATIO AT FS	19.519	-
		ATSA	AERODYNAMIC THROAT AREA AT FS	94.284	IN**2
		CFVS	IDEAL VACUUM THRUST COEFFICIENT AT FS	1.8074	-
		TA	SUSTAIN ACTION TIME	6.60	SEC
L	50	ATEXTA	AERODYNAMIC THROAT AREA REQUIRED FOR MOTOR EXTINGUISHMENT	699.246	IN**2
L	55	EXT	CONTROL - AN INPUT OF 1 CAUSES THE PROGRAM TO DESIGN FOR MOTOR EXTINGUISHMENT	0.	-
L	80	GTYPE	GRAIN TYPE (1 = CONSTANT SURFACE AREA; 2 = VARIABLE SURFACE AREA)	2.	-
L	92	ATMXA	MAXIMUM AERODYNAMIC THROAT AREA	184.296	IN**2
L	93	ATMNA	MINIMUM AERODYNAMIC THROAT AREA	150.788	IN**2
		CTA	COAST TIME (MOTOR SHUTDOWN)	0.0	SEC

---MISCELLANEOUS OPTIONAL INPUTS---

L	1068	RPTIP	PINTLE TIP RADIUS	1.316	IN
L	1069	TB	TOTAL BURN TIME	60.60	SEC
L	1070	NSTT	NUMBER OF STRUTS	3.	-
L	1071	BETAST	STRUT ANGLE	31.993	DEG
L	1072	PHYD	HYDRAULIC SUPPLY PRESSURE	3000.00	PSI
L	1073	LLVDT	LENGTH OF FEEDBACK (LVDT)	1.750	IN
L	1074	ODLVDT	OUTSIDE DIAMETER OF FEEDBACK (LVDT)	0.500	IN
L	1075	ABAL	PER CENT OF PINTLE TIP WHICH IS AREA BALANCED	25.00	-
L	1076	BREXP	PROPELLANT BURN RATE EXPONENT	0.600	-

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                        HARDWARE TEST CASE NO. 1

                PINTLE NOZZLE DESIGN PARAMETERS (PAGE 2)

   ---GEOMETRIC THROAT AREA AND PINTLE SIZING CALCULATIONS---

L 1077  CDB      BOOST DISCHARGE COEFFICIENT                                            0.970      -
L 1078  CDS      SUSTAIN DISCHARGE COEFFICIENT                                          0.870      -
L 1079  CDEXT    EXTINGUISHMENT DISCHARGE COEFFICIENT                                   0.850      -

        ATMING   GEOMETRIC THROAT AREA AT FMAX                                        135.616      IN**2
        ATMAXG   GEOMETRIC THROAT AREA AT FMIN                                        235.269      IN**2
        ATBG     GEOMETRIC THROAT AREA AT FB                                          141.388      IN**2
        ATSG     GEOMETRIC THROAT AREA AT FS                                          108.372      IN**2
        ATEXTG   GEOMETRIC THROAT AREA REQUIRED FOR MOTOR EXTINGUISHMENT              822.642      IN**2
        ATMNG    MINIMUM GEOMETRIC THROAT AREA                                        155.452      IN**2
        ATMXG    MAXIMUM GEOMETRIC THROAT AREA                                        211.834      IN**2

L 1080  BXDDTP   PINTLE EROSION RATE DURING BOOST CONDITIONS                           8.4754      MILS/SEC
L 1081  SXDDTP   PINTLE EROSION RATE DURING SUSTAIN CONDITIONS                         4.2776      MILS/SEC

L 1082  ODP      OUTSIDE DIAMETER OF PINTLE                                           13.156       IN
        ODPE     OUTSIDE DIAMETER OF ERODED PINTLE                                    11.698       IN
        AODP     AREA OF OUTSIDE DIAMETER OF PINTLE                                  135.935       IN**2
        AODPE    AREA OF OUTSIDE DIAMETER OF ERODED PINTLE                           107.480       IN**2

   ---STROKE CALCULATIONS---

L 1083  STR      MAXIMUM PINTLE STROKE                                                  6.965      IN

        XDMAX    AXIAL DISTANCE FROM NOZZLE THROAT TO PINTLE TIP AT FMIN (INITIAL CONDITIONS)     -7.178     IN
        XDMIN    AXIAL DISTANCE FROM NOZZLE THROAT TO PINTLE TIP AT FMAX (ERODED CONDITIONS)       0.830     IN
        XDB      AXIAL DISTANCE FROM NOZZLE THROAT TO PINTLE TIP AT FB (INITIAL CONDITIONS)       -2.778     IN
        XDS      AXIAL DISTANCE FROM NOZZLE THROAT TO PINTLE TIP AT FS (INITIAL CONDITIONS)       -1.060     IN
        XDEXT    AXIAL DISTANCE FROM NOZZLE THROAT TO PINTLE TIP AT EXTINGUISHMENT (INT. COND.)    0.0       IN
        XDMX     AXIAL DISTANCE FROM NOZZLE THROAT TO PINTLE TIP AT ATMXG                         -6.135     IN
        XDMN     AXIAL DISTANCE FROM NOZZLE THROAT TO PINTLE TIP AT ATMNG                         -3.479     IN

L 1084  STRDOT   PINTLE VELOCITY                                                      23.217      IN/SEC
L 1085  INTMC    INTEGRAL OF STRDOT                                                   34.825      IN
        ADOTMX   MAXIMUM THROAT AREA RATE OF CHANGE                                    0.0        IN**2/SEC
        INADOT   INTEGRAL OF ADOT                                                      0.0        IN**2

   ---FORCE AND LOAD CALCULATIONS---

        FTIP     PINTLE TIP FORCE                                                    4205.07      LB
        FAF      ACTUATOR FRICTION FORCE                                              420.51      LB
        FABAL    PRESSURE BALANCING FORCE                                               0.0       LB
        FEXT     ACTUATOR EXTEND FORCE                                                  0.0       LB
        FRET     ACTUATOR RETRACT FORCE                                                 0.0       LB
        FACT     REQUIRED ACTUATOR FORCE                                            17569.46      LB

        AHYD     ACTUATOR AREA REQUIRED TO PRODUCE FACT                                 7.809     IN**2

        FEJ      EJECTION LOAD ACTING ON CENTERBODY                                167828.13      LB
        FSTTT    EJECTION LOAD CARRIED BY EACH STRUT                                65961.13      LB
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HARDWARE TEST CASE NO. 1

TMC ASSEMBLY WEIGHT SUMMARY (ABLATIVE SLEEVE PINTLE)

SYMBOL	DEFINITION	X TO CENTROID (IN)	MOMENT OF INERTIA (LB-IN**2) ROLL	PITCH	WEIGHT (LB)
PNT	PINTLE	-12.143	1257.95	1471.78	62.66
ACT	ACTUATOR	-17.347	395.98	837.15	41.05
CBA	CENTERBODY ASSEMBLY	-17.695	3598.60	5371.06	136.52
SSR	STRUT SUPPORT RING	-8.282	45011.52	22750.46	198.32

SYMBOL	DEFINITION	SAFETY FACTOR	MATERIAL CODE	INSULATION OR STRUCTURE	WEIGHT (LB)	L-NUMBER OF SAFETY FACTOR
PNT	PINTLE				62.66	
PL	PINTLE LINER	1.50	10	I	21.73	L1411
PIN	PINTLE INSULATION	1.50	7	I	31.63	L1414
SM	STRUCTURAL MEMBER	1.25	2	S	9.31	L1417
ACT	ACTUATOR				41.05	
CSS	CENTERSHAFT STRUCTURE	1.25	2	S	9.88	L1429
CSI	CENTERSHAFT INSULATION	1.50	7	I	1.74	L1432
MH	MOVABLE HOUSING	1.25	2	S	29.44	L1435
CBA	CENTERBODY ASSEMBLY				136.52	
CBWS	CENTERBODY WALL STRUCTURE	1.25	2	S	12.82	L1438
CBWI	CENTERBODY WALL INSULATION	1.50	7	I	62.20	L1441
CBDS	CENTERBODY DOME STRUCTURE	1.25	2	S	3.90	L1444
CBDI	CENTERBODY DOME INSULATION	1.50	7	I	18.96	L1447
STTS	STRUT STRUCTURE	1.25	2	S	7.96	L1450
STTI	STRUT INSULATION	1.50	7	I	30.68	L1453
SSR	STRUT SUPPORT RING	1.25	2	S	198.32	L1456

I MEANS MATERIAL IS FOUND IN THE INSULATION MATERIALS TABLE
S MEANS MATERIAL IS FOUND IN THE STRUCTURAL MATERIALS TABLE

L-NOS ARE CONSECUTIVE FROM LEFT TO RIGHT

HARDWARE TEST CASE NO. 1

ABLATIVE SLEEVE PINTLE AND ACTUATOR DIMENSIONS

RODP	RADIUS TO OUTSIDE DIAMETER OF PINTLE	6.578	IN
RODSS	RADIUS TO OUTSIDE DIAMETER OF SLIDING SEAL	5.697	IN
LTIP	LENGTH OF PINTLE TIP	3.828	IN
TLOD	TOTAL LINER ON OUTSIDE DIAMETER OF PINTLE SHAFT	1.402	IN
RODSM	RADIUS TO OUTSIDE DIAMETER OF STRUCTURAL MEMBER	4.294	IN
TKSM	THICKNESS OF STRUCTURAL MEMBER	0.142	IN
RIDSM	RADIUS TO INSIDE DIAMETER OF STRUCTURAL MEMBER	4.152	IN
TLID	TOTAL LINER ON INSIDE DIAMETER OF PINTLE SHAFT	1.402	IN
RIDSP	RADIUS TO INSIDE DIAMETER OF SLEEVE PINTLE	2.750	IN
RIDACW	RADIUS TO INSIDE DIAMETER OF ACTUATOR CYLINDER WALL	3.170	IN
TKACW	THICKNESS OF ACTUATOR CYLINDER WALL	0.100	IN
RODACW	RADIUS TO OUTSIDE DIAMETER OF ACTUATOR CYLINDER WALL	3.270	IN
WDPST	WIDTH OF ACTUATOR PISTON	0.979	IN
TKEWL	THICKNESS OF ACTUATOR END WALLS	0.734	IN
WDSSR	WIDTH OF SLIDING SEAL RING	1.075	IN
LAMH	LENGTH OF ACTUATOR MOVABLE HOUSING	9.412	IN
TKCSIN	THICKNESS OF CENTERSHAFT INSULATION	1.402	IN
LSM	LENGTH OF STRUCTURAL MEMBER	8.707	IN
LAPA	TOTAL LENGTH OF ACTUATOR-PINTLE ASSEMBLY	17.779	IN
TKCSCW	THICKNESS OF CENTERSHAFT CYLINDER WALL	0.100	IN
TKCSEW	THICKNESS OF CENTERSHAFT END WALL	0.100	IN
LCSS	LENGTH OF CENTERSHAFT STRUCTURE	16.377	IN

HARDWARE TEST CASE NO. 1 .

STRUTTED CENTERBODY DIMENSIONS

XDOME	AXIAL DISTANCE FROM THROAT TO FORWARD EDGE OF CENTERBODY DOME	-28.613	IN
LCBD	LENGTH OF CENTERBODY DOME	4.699	IN
TKIND	THICKNESS OF CENTERBODY DOME INSULATION	1.800	IN
TKCBDS	THICKNESS OF CENTERBODY DOME STRUCTURE	0.100	IN
RIDCBW	RADIUS TO INSIDE DIAMETER OF CENTERBODY WALL	5.697	IN
TKCBWL	THICKNESS OF CENTERBODY WALL	0.100	IN
RODCBW	RADIUS TO OUTSIDE DIAMETER OF CENTERBODY	5.797	IN
TKCBWI	THICKNESS OF CENTERBODY WALL INSULATION	2.003	IN
RODICB	RADIUS TO OUTSIDE DIAMETER OF INSULATED CENTERBODY	7.800	IN
LCBWS	LENGTH OF CENTERBODY WALL STRUCTURE	12.549	IN
LCBWI	LENGTH OF CENTERBODY WALL INSULATION	13.951	IN
XFHST	AXIAL DISTANCE FROM THROAT TO INTERSECTION OF FORWARD EDGE OF STRUT STRUCTURE AND CENTERBODY WALL STRUCTURE	-23.914	IN
RFHST	RADIAL DISTANCE FROM CENTERLINE TO INTERSECTION OF FORWARD EDGE OF STRUT STRUCTURE AND CENTERBODY WALL STRUCTURE	5.797	IN
XEPF	AXIAL DISTANCE FROM THROAT TO INTERSECTION OF FORWARD EDGE OF STRUT STRUCTURE AND SURFACE OF NOZZLE LINER	-10.923	IN
REPF	RADIAL DISTANCE FROM CENTERLINE TO INTERSECTION OF FORWARD EDGE OF STRUT STRUCTURE AND SURFACE OF NOZZLE LINER	13.912	IN
DSTTS	DIAMETER OF STRUT STRUCTURE	0.843	IN
TINSTT	THICKNESS OF STRUT INSULATION	2.003	IN
LFSTTS	LENGTH OF FORWARD EDGE OF STRUT STRUCTURE	17.374	IN
LASTTS	LENGTH OF AFT EDGE OF STRUT STRUCTURE	16.219	IN
LSSR	LENGTH OF STRUT SUPPORT RING	5.442	IN
HSSR	HEIGHT OF STRUT SUPPORT RING	1.300	IN

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THE FOLLOWING CONDITIONS OCCURED IN THE NOZZLE DESIGN CALCULATIONS

               AN INVALID SPECIFICATION HAS BEEN MADE FOR
               THROAT TYPE

               AN INVALID SPECIFICATION HAS BEEN MADE FOR
               CASE TYPE
```

HARDWARE TEST CASE NO. 1

TORQUE SUBROUTINE

INPUT PARAMETERS

L 5751	PBP1	RATIO OF BASE PRESSURE TO FREE STREAM STATIC PRESSURE	0.50	- -
L 5752	MU	FRICTION COEFFICIENT	0.05	- -
L 5750	CTR1	O-RING FRICTION COEFFICIENT DUE TO COMPRESSION	2.5	- -
L 5757	GMAX	MAXIMUM ACCELERATION OF GRAVITY ENCOUNTERED	1.0000	G
L 5755	TFTM	FRICTION TORQUE MULTIPLIER (PARTICLE DEPOSITION)	2.5000	- -

INPUT FROM OTHER SUBROUTINES

MEOP	MAXIMUM CHAMBER PRESSURE	1109.	PSIA
XPIV	DISTANCE FROM THROAT TO PIVOT	-18.03	IN
DTINT	INITIAL THROAT DIAMETER	16.42	IN
DELMX	MAX VECTOR ANGLE	4.0	DEG
MUR	SHEAR MODULUS OF RUBBER SHIMS	24.	PSI
ASEAL	SEAL RADIUS OF CURVATURE	19.25	IN
TR	THICKNESS OF RUBBER SHIMS	0.025	IN
NR	NUMBER OF RUBBER SHIMS	18.	- -
BETA1	INSIDE SEAL ANGLE MEASURED FROM CENTERLINE	45.0	DEG
BETA2	OUTSIDE SEAL ANGLE MEASURED FROM CENTERLINE	48.9	DEG
BETAM	MEAN SEAL ANGLE MEASURED FROM CENTERLINE	46.9	DEG
FEJDES	BLOWOUT LOAD	358861.	LB
DOR	O-RING CROSS SECTIONAL DIAMETER	0.0	IN
RLI	INSIDE RADIUS OF BEARING SURFACE	0.0	IN
RLO	OUTSIDE RADIUS OF BEARING SURFACE	0.0	IN
ANGQ	ANGLE BETWEEN CENTERLINE AND OUTSIDE RADIUS	0.0	DEG
ANGP	ANGLE BETWEEN CENTERLINE AND INSIDE RADIUS	0.0	DEG
ANOR	ANGLE BETWEEN CENTERLINE AND O-RING	0.0	DEG
DBALL	DIAMETER OF GIMBAL BEARING	0.0	IN
BD	BASE DIAMETER	65.0	IN
R15	RADIUS OF NOZZLE EXIT	21.5	IN
R7	RADIUS AT STATION 7	8.6	IN
X15	DISTANCE FROM NOZZLE THROAT TO EXIT	40.0	IN
X7	DISTANCE FROM NOZZLE THROAT TO STATION 7	1.9	IN
THETAI	MAXIMUM EXIT HALF ANGLE	23.0	DEG
DELTH	TURNBACK ANGLE	10.0	DEG
THTICE	EQUIVALENT EXIT HALF ANGLE	18.3	DEG
ELXIF	AXIAL LOCATION OF MOTOR FLANGE	1000.0	FEET
ELXI	AXIAL DISTANCE FROM THROAT TO FLANGE	12.0	IN
ESPL	EXPANSION RATIO AT SPLIT LINE	0.0	- -
EPIV	EXPANSION RATIO AT PIVOT	0.0	- -
EINT	EXPANSION RATIO AT EXIT	0.0	- -
XSL	DISTANCE FROM THROAT TO SPLITLINE	12.0	IN
TPNOZ	NOZZLE TYPE	5.	- -
CONTRL	TVC CODE	6.	- -
FVMX	AXIAL THRUST	220000.0	LB
WMOV	WEIGHT OF MOVABLE PORTION OF NOZZLE	692.047	LB
XNMAX	AXIAL STATION OF AFT END OF SKIRT N=MAXIMUM	1000.0	FEET
SNMAX	SKIRT FLARE ANGLE N=MAXIMUM	0.0	DEG
PAES	STATIC PRESSURE AT AFT END OF SKIRT N=MAXIMUM	0.0	PSIA
MACH1	MACH NO. AT AFT END OF SKIRT N=MAXIMUM	3.0	- -

HARDWARE TEST CASE NO. 1

TORQUE SUBROUTINE

OUTPUT

TIME	VAC THRUST	DATT	PTORQ	TAERO	TOFF	TSEAL	TBOOT	TGRAV	TEAT	TTOT
0.0	0.0	16.423	0.	0.	0.	117037.	17556.	14491.	0.	134593.
0.0	220000.0	16.423	924.	88351.	30125.	117018.	17553.	14491.	0.	253046.
20.000	220000.0	16.762	924.	91790.	31381.	117018.	17553.	14491.	0.	257742.
54.000	220000.0	17.338	924.	97762.	33577.	117018.	17553.	14491.	0.	265909.
54.000	64000.0	17.338	132.	13988.	4804.	117035.	17555.	14491.	0.	153382.
60.000	64000.0	17.390	132.	14065.	4833.	117035.	17555.	14491.	0.	153488.
60.600	64000.0	17.395	132.	14073.	4836.	117035.	17555.	14491.	0.	153498.

* ALL TORQUE COMPONENTS ARE IN (IN-LB)
TIME VALUES ARE IN (SEC)
DATT = THROAT DIAMETER AT TIME IN (IN)
PTORQ = PRESSURE FOR TORQUE CALCULATIONS IN (PSI)
(CONSULT USERS MANUAL FOR EXPLANATION AND EQUATION FOR EACH TORQUE COMPONENT LISTED ABOVE)

MAXIMUM TOTAL TORQUE - - - - 265909.

MAXIMUM TOTAL TORQUE

TIME	54.000	SEC
TAERO	97762.	IN-LB
TOFF	33577.	IN-LB
TSEAL	117018.	IN-LB
TBOOT	17555.	IN-LB

TOTAL - - - - - - 265909. IN-LB

THRUST VECTOR CONTROL--THRUST MODULATION CONTROL--ROLL CONTROL

ACTUATION SYSTEM SUBROUTINE

NOZZLE TYPE	MOVABLE
TVC ACTUATOR	LINEAR
TVC POWER SYSTEM	SYSTEM NOT SPECIFIED
TMC SYSTEM	REQUIRED
ROLL SYSTEM	NOT REQD

OPTIONAL INPUT PARAMETERS

CSTAR	TVC	GENERATOR CHARACTERISTIC VELOCITY	3724.	FT/SEC
GAMMA	TVC	GENERATOR GAS SPECIFIC HEAT RATIO	1.28	------
MBAR	TVC	GENERATOR MEAN MOLECULAR WEIGHT	19.24	------
PGEN	TVC	GENERATOR PRESSURE	1000.	PSI
PSU	TVC	HYDRAULIC SUPPLY PRESSURE	3000.	PSI
RHOG	TVC	GENERATOR GAS DENSITY	0.000463	LB/IN**3
TGEN	TVC	GENERATOR GAS TEMPERATURE	2245.	DEG R

TVC INPUT PARAMETERS---OTHER PROGRAMS

BD	MISSILE CASE DIAMETER	65.0	IN
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
DTINT	DIAMETER OF THROAT--INITIAL	16.4	IN
FAVP	HOT GAS PINTLE ACTUATOR FORCE	0.0	LB
INP	INTEGRAL OF MISSILE PITCH RATE	90.0	DEG
INY	INTEGRAL OF MISSILE YAW RATE	90.0	DEG
LAM	ACTUATION MOMENT ARM	0.0	IN
TA	ACTION TIME	60.6	SEC
TT	NOZZLE OR FIN TORQUE	265908.8	IN-LB
XN1	RATIO OF HOT GAS JET PIPE ANGLE, HOT GAS ROTATING VALVE ANGLE OR JET TAB ANGLE TO TVC ANGLE	0.0	DEG/DEG
XN2	RATIO OF HOT GAS PINTLE TRAVEL TO TVC ANGLE	0.0	IN/DEG
XN3	RATIO OF HINGED NOZZLE ANGLE TO TVC ANGLE	2.000	DEG/DEG

TMC INPUT PARAMETERS--OTHER PROGRAMS

AHYD	TMC ACTUATOR AREA	7.81	IN**2
BD	MISSILE CASE DIAMETER	65.0	IN
FATMC	TMC ACTUATOR FORCE	17569.5	LB
INTMC	INTEGRAL OF TMC ACTUATOR RATE	34.8	IN
PHYD	TMC HYDRAULIC SUPPLY PRESSURE	3000.	PSI
STKDOT	TMC ACTUATOR RATE	23.2	IN/SEC
STR	TMC ACTUATOR STROKE	7.0	IN
TA	ACTION TIME	60.6	SEC

TVC SYSTEM -- TURBINE SYSTEM

NUMACT	NUMBER OF TVC ACTUATORS	2.	
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
TT	NOZZLE OR FIN TORQUE	265908.8	IN-LB
TA	ACTION TIME	60.6	SEC
Q	TVC ACTUATOR FLOW	46.4	CIS
QTMC	TMC ACTUATOR FLOW	181.3	CIS
QPY	TOTAL HYDRAULIC PUMP FLOW	172.8	CIS
HP	HYDRAULIC HORSEPOWER	78.57	HP
FRGT	TVC & TMC GAS FLOW RATE	0.2897	LB/SEC
FRRS	ROLL GAS FLOW RATE	0.0	LB/SEC
HPGTS	TOTAL GAS HORSEPOWER	261.9	HP
SIGMA	TVC GENERATOR MASS FRACTION	0.706	LB/LB
ENGA	LINEAR ACTUATOR ENERGY	1547.	FT-LB
VRU	HYDRAULIC RESERVOIR VOLUME	440.8	IN**3
IDTVC	HYDRAULIC LINE I.D.	0.752	IN

WEIGHT BREAKDOWN

WTU	TURBINE	35.71	LB
WGG	GAS GENERATOR	24.88	LB
WVOP	HYDRAULIC PUMP	21.63	LB
WSATVC	SERVO ACTUATORS	16.75	LB
WRU	HYDRAULIC RESERVOIR	1[illegible].16	LB
WHLTVC	HYDRAULIC LINES & FITTINGS	6.28	LB
WF	HYDRAULIC FILTER	6.74	LB
WDC	HYDRAULIC DISCONNECTS	1.23	LB
WOOB	OIL ON BOARD	14.73	LB
	MSC MOUNTING HARDWARE	14.31	LB
WTS	TOTAL TURBINE SYSTEM	157.42	LB

TVC SYSTEM -- SERVO PUMP SYSTEM

NUMACT	NUMBER OF TVC ACTUATORS	2.	
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
TT	NOZZLE OR FIN TORQUE	265908.8	IN-LB
TA	ACTION TIME	60.6	SEC
Q	TVC ACTUATOR FLOW	46.4	CIS
QT4C	TMC ACTUATOR FLOW	181.3	CIS
QPY	TOTAL HYDRAULIC PUMP FLOW	172.8	CIS
HP	HYDRAULIC HORSEPOWER	78.57	HP
FRGT	TVC & TMC GAS FLOW RATE	0.2897	LB/SEC
FRRS	ROLL GAS FLOW RATE	0.0	LB/SEC
HPGTS	TOTAL GAS HORSEPOWER	261.9	HP
SIGMA	TVC GENERATOR MASS FRACTION	0.706	LB/LB
ENGA	LINEAR ACTUATOR ENERGY	1547.	FT-LB
VRU	HYDRAULIC RESERVOIR VOLUME	440.8	IN**3
IDTVC	HYDRAULIC LINE I.D.	0.752	IN

WEIGHT BREAKDOWN

WSP	SERVO PUMPS	36.01	LB
WGG	GAS GENERATOR	24.88	LB
WTGSP	TURBINE & GEAR BOX	28.83	LB
WSATVC	SERVO ACTUATORS	16.75	LB
WRU	HYDRAULIC RESERVOIR	15.16	LB
WHLTVC	HYDRAULIC LINES & FITTINGS	6.28	LB
WF	HYDRAULIC FILTER	6.74	LB
WDC	HYDRAULIC DISCONNECTS	1.23	LB
WOOB	OIL ON BOARD	14.73	LB
	MSC MOUNTING HARDWARE	15.06	LB
WSPS	TOTAL SERVO PUMP SYSTEM	165.08	LB

TVC SYSTEM -- WARM GAS MOTOR PUMP SYSTEM

NUMACT	NUMBER OF TVC ACTUATORS	2.	
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
TT	NOZZLE OR FIN TORQUE	265908.8	IN-LB
TA	ACTION TIME	60.6	SEC
Q	TVC ACTUATOR FLOW	46.4	CIS
QTMC	TMC ACTUATOR FLOW	181.3	CIS
QPY	TOTAL HYDRAULIC PUMP FLOW	172.8	CIS
HP	HYDRAULIC HORSEPOWER	78.57	HP
FRGT	TVC & TMC GAS FLOW RATE	0.2897	LB/SEC
FRRS	ROLL GAS FLOW RATE	0.0	LB/SEC
HPGTS	TOTAL GAS HORSEPOWER	261.9	HP
SIGMA	TVC GENERATOR MASS FRACTION	0.706	LB/LB
ENGA	LINEAR ACTUATOR ENERGY	1547.	FT-LB
VRU	HYDRAULIC RESERVOIR VOLUME	440.8	IN**3
IDTVC	HYDRAULIC LINE I.D.	0.752	IN

WEIGHT BREAKDOWN

WWGMP	WARM GAS MOTOR PUMP	54.58	LB
WGG	GAS GENERATOR	24.88	LB
WWGPV	WARM GAS RELIEF VALVE	0.58	LB
WSATVC	SERVO ACTUATORS	15.75	LB
WRU	HYDRAULIC RESERVOIR	15.16	LB
WHLTVC	HYDRAULIC LINES & FITTINGS	6.28	LB
WF	HYDRAULIC FILTER	6.74	LB
WDC	HYDRAULIC DISCONNECTS	1.23	LB
WOOB	OIL ON BOARD	14.73	LB
	MSC MOUNTING HARDWARE	14.09	LB
WWGMPS	TOTAL WARM GAS MOTOR PUMP SYSTEM	155.02	LB

TVC SYSTEM -- ELECTRIC MOTOR PUMP

NUMACT	NUMBER OF TVC ACTUATORS	2.	
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
TT	NOZZLE OR FIN TORQUE	265908.8	IN-LB
TA	ACTION TIME	60.6	SEC
Q	TVC ACTUATOR FLOW	46.4	CIS
QTMC	TMC ACTUATOR FLOW	181.3	CIS
QPY	TOTAL HYDRAULIC PUMP FLOW	172.8	CIS
HP	HYDRAULIC HORSEPOWER	78.57	HP
ENGA	LINEAR ACTUATOR ENERGY	1547.0	FT-LB
HPH	HORSEPOWER HOUR	1.32	HP-HR
VRU	HYDRAULIC RESERVOIR VOLUME	440.8	IN**3
IDTVC	HYDRAULIC LINE I.D.	0.752	IN

WEIGHT BREAKDOWN

WEMP	ELECTRIC MOTOR PUMP	379.76	LB
WB	BATTERY	140.94	LB
WSATVC	SERVO ACTUATORS	16.75	LB
WRU	HYDRAULIC RESERVOIR	15.16	LB
WHLTVC	HYDRAULIC LINES & FITTINGS	6.28	LB
WF	HYDRAULIC FILTER	6.74	LB
WDC	HYDRAULIC DISCONNECTS	1.23	LB
WCOB	OIL ON BOARD	14.73	LB
	MSC MOUNTING HARDWARE	58.16	LB
WEMPS	TOTAL ELECTRIC MOTOR PUMP SYSTEM	639.76	LB

TVC SYSTEM -- WARM GAS BLOWDOWN

NUMACT	NUMBER OF TVC ACTUATORS	2.	
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
TT	NOZZLE OR FIN TORQUE	265908.8	IN-LB
TA	ACTION TIME	60.6	SEC
INP	INTEGRAL OF MISSILE PITCH RATE	90.0	DEG
INY	INTEGRAL OF MISSILE YAW RATE	90.0	DEG
ENGA	LINEAR ACTUATOR ENERGY	1547.0	FT--LB
QAB	TVC ACTUATOR FLOW	139.2	CIS
QTMCB	TMC ACTUATOR FLOW	543.9	CIS
QPYB	TOTAL HYDRAULIC FLOW	783.1	CIS
IDTVCB	HYDRAULIC LINE I.D.	1.095	IN
VOLEX	VOLUME OF OIL EXPELLED	2978.1	IN**3
FRTVCB	TVC & TMC GAS FLOW RATE	0.363	LB/SEC
FRRS	ROLL GAS FLOW RATE	0.0	LB/SEC
HPGBT	GAS HORSEPOWER	327.8	HP
SIGMB	GENERATOR MASS FRACTION	0.718	LB/LB

WEIGHT BREAKDOWN

WBGG	GAS GENERATOR	30.58	LB
WSATVC	SERVO ACTUATORS	16.75	LB
WWGRVB	WARM GAS RELIEF VALVE	2.22	LB
WBDA	BLOWDOWN ACCUMULATOR	79.35	LB
WHLTVB	HYDRAULIC LINES & FITTINGS	4.00	LB
WFB	HYDRAULIC FILTER	30.33	LB
WDCB	HYDRAULIC DISCONNECTS	2.21	LB
WOB	OIL ON BOARD	99.78	LB
	MSC MOUNTING HARDWARE	26.52	LB
WBDS	TOTAL WARM GAS BLOWDOWN SYSTEM	291.75	LB

TVC SYSTEM -- SELF PRESSURIZING SYSTEM

NUMACT	NUMBER OF TVC ACTUATORS	2.	
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
TT	NOZZLE OR FIN TORQUE	265908.8	IN-LB
TA	ACTION TIME	60.6	SEC
INP	INTEGRAL OF MISSILE PITCH RATE	90.0	DEG
INY	INTEGRAL OF MISSILE YAW RATE	90.0	DEG
ENGA	LINEAR ACTUATOR ENERGY	1547.0	FT--LB
QAB	TVC ACTUATOR FLOW	139.2	CIS
QTMCB	TMC ACTUATOR FLOW	543.9	CIS
QPYB	TOTAL HYDRAULIC FLOW	783.1	CIS
IDTVCB	HYDRAULIC LINE I.D.	1.095	IN
VOLEX	VOLUME OF OIL EXPELLED	2978.1	IN**3
FRTVCB	TVC & TMC GAS FLOW RATE	0.363	LB/SEC
FRRS	ROLL GAS FLOW RATE	0.0	LB/SEC
HPGRT	GAS HORSEPOWER	327.8	HP
SIGMB	GENERATOR MASS FRACTION	0.718	LB/LB

WEIGHT BREAKDOWN

WGGGB	GAS GENERATOR GRAIN	21.97	LB
WGGCI	GAS GENERATOR CASE	4.31	LB
WSATVC	SERVO ACTUATORS	16.75	LB
WWGRVB	WARM GAS RELIEF VALVE	2.22	LB
WBDA	BLOWDOWN ACCUMULATOR	79.35	LB
WHLTVB	HYDRAULIC LINES & FITTINGS	4.00	LB
WFB	HYDRAULIC FILTER	30.33	LB
WDCB	HYDRAULIC DISCONNECTS	2.21	LB
WOB	OIL ON BOARD	99.78	LB
	MSC MOUNTING HARDWARE	26.09	LB
WSPAPU	TOTAL SELF PRESSURIZING SYSTEM	287.02	LB

TVC SYSTEM -- ELECTRO MECHANICAL

NUMACT	NUMBER OF TVC ACTUATORS	[illegible]	
DELDOT	TVC SLEW RATE	20.0	DEG/SEC
DELMXI	MAXIMUM TVC VECTOR ANGLE	4.0	DEG
TT	NOZZLE OR FIN TORQUE	265908.8	[illegible]-LB
TA	ACTION TIME	60.6	SEC
HPATVC	TVC ACTUATOR INPUT HORSEPOWER	14.1	HP
HPATMC	TMC ACTUATOR INPUT HORSEPOWER	61.8	HP
HPHREM	TOTAL HORSEPOWER HOUR	7.569	HP-HR

WEIGHT BREAKDOWN

WSAEM	TVC ACTUATORS	174.66	LB
WBEM	BATTERY	564.66	LB
	MSC MOUNTING WEIGHT	73.93	LB
WEMS	TOTAL ELECTRO MECHANICAL SYSTEM	813.26	LB

TVC SYSTEM -- ELECTRO PNEUMATIC

NUMACT	NUMBER OF TVC ACTUATORS	2.	
FRTVC	TVC ACTUATOR FLOW RATE	0.0867	LB/SEC
FRTMC	TMC ACTUATOR FLOW RATE	0.3808	LB/SEC
FRRS	ROLL SYSTEM FLOW RATE	0.0	LB/SEC
FRTOT	TOTAL FLOW RATE	0.5034	LB/SEC
ENGTVC	TVC ACTUATOR ENERGY	1547.0	FT-LBS
AACT	TVC ACTUATOR GAS AREA	0.010	IN**2
ADUCT	DUCT AREA	0.024	IN**2
DIADUC	DUCT DIAMETER	0.174	IN
THKDUC	DUCT THICKNESS	0.021	IN
HPPNU	GAS HORSEPOWER	455.09	HP
SIGMPU	GENERATOR MASS FRACTION	0.728	LB/LB

WEIGHT BREAKDOWN

WGGPNU	GAS GENERATOR	41.89	LB
WTDUCT	WARM GAS DUCT	0.43	LB
WRVPNU	RELIEF VALVE	3.83	LB
WPNUSA	SERVO ACTUATORS	402.39	LB
	MSC MOUNTING HARDWARE	44.85	LB
WPNUS	TOTAL ELECTRO PNEJMATIC SYSTEM	493.39	LB

TMC SYSTEM -- HYDRAULIC

PSU	TVC HYDRAULIC SUPPLY PRESSURE	3000.	PSI
PHYD	TMC HYDRAULIC SUPPLY PRESSURE	3000.	PSI
AHYD	TMC ACTUATOR AREA	7.81	IN**2
BD	MISSILE CASE DIAMETER	65.0	IN
FATMC	TMC ACTUATOR FORCE	17569.5	LB
INTMC	INTEGRAL OF TMC ACTUATOR RATE	34.8	IN
STKDOT	TMC ACTUATOR RATE	23.2	IN/SEC
STR	TMC ACTUATOR STROKE	7.0	IN
TA	ACTION TIME	60.6	SEC
QTMC	TMC ACTUATOR FLOW	181.3	CIS
IDTMC	HYDRAULIC LINE I.D.	0.955	IN

WEIGHT BREAKDOWN

WSVTMC	TMC SERVO VALVE	5.54	LB
WHLTMC	TMC HYDRAULIC LINE & FITTINGS	3.77	LB
WOTMC	OIL IN LINES	3.35	LB
	MSC MOUNTING HARDWARE	1.27	LB
WTMCS	TOTAL TMC SYSTEM	13.93	LB

NOTE: TMC HYDRAULIC ACTUATOR WEIGHT INCLUDED IN NOZZLE PROGRAM

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THE FOLLOWING CONDITIONS OCCURED IN THE ACTUATION CALCULATIONS

          ROLL SYSTEM NOT REQUIRED

          EXTRAPOLATION HAS OCCURED IN THE FOLLOWING
          TABLE.  THE ARGUMENT WAS   7.8566559E 01
             WEIGHT OF ELECTRIC MOTOR PUMP VS OUTPUT HORSEPOWER

          EXTRAPOLATION HAS OCCURED IN THE FOLLOWING
          TABLE.  THE ARGUMENT WAS   7.8566559E 01
             WEIGHT OF WARM GAS MOTOR PUMP VS HYDRAULIC HORSEPOWER OUTPUT

          EXTRAPOLATION HAS OCCURED IN THE FOLLOWING
          TABLE.  THE ARGUMENT WAS   7.8308667E 02
             WEIGHT OF HYDRAULIC TEE FILTERS VS FLOW RATE

          EXTRAPOLATION HAS OCCURED IN THE FOLLOWING
          TABLE.  THE ARGUMENT WAS   2.9781252E 03
             WEIGHT VS VOLUME OF BLOWDOWN ACCUMULATOR

          EXTRAPOLATION HAS OCCURED IN THE FOLLOWING
          TABLE.  THE ARGUMENT WAS   1.1480961E 00
             ROTARY ELECTROMECHANICAL ACTUATOR WEIGHT VS OUTPUT HORSEPOWER

          EXTRAPOLATION HAS OCCURED IN THE FOLLOWING
          TABLE.  THE ARGUMENT WAS   1.7910128E 00
             LINEAR ELECTROMECHANICAL ACTUATOR WEIGHT VS OUTPUT HORSEPOWER
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HARDWARE TEST CASE NO. 1

INPUT FROM NOZZLE DESIGN SUBROUTINE

INPUT PARAMETER	DESCRIPTION		
TPNOZ	NOZZLE TYPE	5	-
CONTRL	TVC TYPE	6	-
PCLOC	PIVOT CENTER CODE	2	-
TPT	THROAT INSERT CODE	3	-
TPGEO	CONTOUR CODE	2	-
HCUFLG	HONEYCOMB STRUCTURE FLAG	0	-
ELXNF	NOZZLE TO CASE INTERFACE STATION	1000.0000	FT
DIACSF	CASE DIAMETER	65.0000	IN
XNOP	AXIAL LOCATION OF CENTER OF EXIT CONE CONTOUR ARC	105.1207	IN
YNOP	RADIAL LOCATION OF CENTER OF EXIT CONE CONTOUR ARC	-234.5101	IN
GAMFN	RADIUS OF ARC SIMULATING EXIT CONE CONTOUR	264.1086	IN
REP	RADIUS OUT OF THROAT	4.9269	IN
THETAC	INLET ANGLE	45.0000	DEG
THETAI	EXIT CONE HALF ANGLE	23.0000	DEG
RSPL	SPLIT LINE RADIUS	19.2491	IN
XPIV	MOVABLE NOZZLE PIVOT LOCATION FROM THROAT	-18.0327	IN
ASEAL	RADIUS TO CENTER OF FLEXIBLE SEAL	19.2491	IN
XOO	AXIAL DISTANCE FROM PIVOT TO POINT ON OUTER SEAL RADIUS	13.2004	IN
XIO	AXIAL DISTANCE FROM PIVOT TO POINT ON INNER SEAL RADIUS	12.2074	IN
ROO	RADIAL DISTANCE TO SEAL AT XOO	14.8903	IN
RIO	RADIAL DISTANCE TO SEAL AT XIO	14.1187	IN
XOI	AXIAL DISTANCE FROM PIVOT TO POINT ON OUTER SEAL RADIUS	14.1209	IN
XII	AXIAL DISTANCE FROM PIVOT TO POINT ON INNER SEAL RADIUS	13.1012	IN
ROI	RADIAL DISTANCE TO SEAL AT XOI	14.0205	IN
RII	RADIAL DISTANCE TO SEAL AT XII	13.2017	IN
ROT	FLEXIBLE SEAL OUTER RADIUS	19.8991	IN
RIN	FLEXIBLE SEAL INNER RADIUS	18.5991	IN
TR	THICKNESS OF RUBBER SHIM	0.0250	IN
TRNO	NUMBER OF RUBBER SHIMS	18.0000	-
TM	THICKNESS OF METAL SHIM	0.0500	IN
TMNO	NUMBER OF METAL SHIMS	17.0000	-
RHORUB	DENSITY OF RUBBER SHIMS	0.0470	LB/IN**3
RHOMET	DENSITY OF METAL SHIMS	0.2760	LB/IN**3

HARDWARE TEST CASE NO. 1

INPUT FROM NOZZLE DESIGN SUBROUTINE (INSULATION AND STRUCTURAL SHELLS)

NOZZLE STATION NUMBER		(STATION LOCATION) INCHES X	Y	(MATERIAL THICKNESS INCHES) EXPENDED LINER	CHARRED LINER	VIRGIN LINER	BACKUP INSUL	STRUCTURE	(MATERIAL DENSITIES LB/IN**3) LINER	CHAR	BACKUP	STRUCTURE
1		12.008	17.548	0.0	0.5493	0.2746	0.2139	0.3032	0.0	0.0	0.0	0.0
2	UP	-5.925	16.510	0.0	0.5493	0.2746	0.2139	0.2972	0.04640	0.02300	0.06600	0.28300
2	DN	-5.892	16.150	0.0	0.6662	0.3331	0.0600	0.0	0.0	0.0	0.0	0.0
3	UP	-12.347	15.836	0.4902	0.6662	0.5782	0.0600	0.0	0.05210	0.03760	0.06600	0.0
4	DN	-12.847	15.836	0.4902	0.4661	0.2451	0.2139	0.0	0.0	0.0	0.0	0.0
5	UP	-8.212	11.200	0.7454	0.4661	0.3727	0.2139	0.0	0.05210	0.03760	0.06600	0.0
5	DN	-8.212	11.200	0.3838	0.0	0.9998	0.4145	0.0	0.0	0.0	0.0	0.0
6		0.0	8.212	0.4859	0.0	0.9998	0.1787	0.0	0.05060	0.0	0.06600	0.0
7	UP	1.925	8.603	0.2549	0.0	0.9998	0.2083	0.0	0.05060	0.0	0.06600	0.0
7	DN	1.925	8.603	0.4950	0.6303	0.1238	0.2139	0.1000	0.0	0.0	0.0	0.0
8	UP	16.364	14.238	0.1194	0.5302	0.0299	0.2139	0.0	0.05210	0.03760	0.06600	0.0
8	DN	16.364	14.238	0.1194	0.5302	0.0299	0.2139	0.0	0.0	0.0	0.0	0.0
12	UP	18.369	14.944	0.0	0.0	0.0	0.0	0.1000	0.0	0.0	0.0	0.28300
12	DN	18.369	14.944	0.0	0.0	0.0	0.0	0.1935	0.0	0.0	0.0	0.0
14	UP	28.385	18.205	0.0995	0.4613	0.0249	0.2139	0.0	0.05210	0.03760	0.06600	0.0
14	DN	28.385	18.205	0.0995	0.4613	0.0249	0.2139	0.0	0.0	0.0	0.0	0.0
15		40.025	21.451	0.0662	0.3398	0.0166	0.2139	0.0500	0.05210	0.03760	0.06600	0.07000

HARDWARE TEST CASE NO. 1

INPUT FROM NOZZLE DESIGN SUBROUTINE (STRUCTURAL AND INSULATION RINGS)

(DESCRIPTION)	(DISTANCE TO CENTROID INCHES) AXIAL	RADIAL	(THICKNESS INCHES) AXIAL	RADIAL	(WALL THICKNESS INCHES) AXIAL	RADIAL	(DENSITY) LB/IN**3
STRUCTURAL RINGS							
FLANGE	12.231	17.752	0.4465	2.4840			0.28300
MOVABLE EXTENSION	-2.784	13.300	11.2179	0.2034			0.28300
EXIT RING	17.597	16.961	1.0748	1.1385	0.537	0.569	0.28300
FWD. END RING	-5.428	13.660	3.0746	1.3522			0.28300
AFT. END RING	-4.372	14.455	2.6281	1.2565			0.28300

HARDWARE TEST CASE NO. 1

MASS PROPERTIES SUBROUTINE OUTPUT

COMPONENT IDENTIFICATION NUMBER AND DEFINITION			WEIGHT (POUNDS)	CENTER OF GRAVITY (INCHES)			MOMENT OF INERTIA (SLUG-FEET**2)		
ID. NUMBER	DEFINITION			LONG.	LAT.	VERT.	PITCH	ROLL	YAW
127	TOTAL SYSTEM		1668.587	11988.414	0.0	0.0	167.878	196.687	167.878
126	TOTAL NOZZLE		1061.081	11991.699	0.0	0.0	137.442	186.452	137.442
125	NOZZLE INSULATION TOTAL		507.240	11993.191	0.0	0.0	78.978	98.357	78.978
6	INSULATION	NOZ STA 1 - 2	97.348	11991.070	0.0	0.0	3.423	5.716	3.423
5	BACKUP		25.647	11991.027	0.0	0.0	0.872	1.436	0.872
4	LINER		71.702	11991.094	0.0	0.0	2.552	4.280	2.552
3	VIRGIN		23.505	11991.135	0.0	0.0	0.817	1.356	0.817
2	CHAR		23.890	11991.156	0.0	0.0	0.794	1.449	0.794
1	EXPENDED		24.307	11991.027	0.0	0.0	0.941	1.474	0.941
12	INSULATION	NOZ STA 2 - 3	[illegible].572	11977.402	0.0	0.0	7.097	13.778	7.097
10	LINER		72.572	11977.406	0.0	0.0	7.097	13.778	7.097
9	VIRGIN		16.555	11976.352	0.0	0.0	4.089	7.909	4.039
8	CHAR		24.488	11977.684	0.0	0.0	0.816	1.568	0.816
7	EXPENDED		31.530	11977.754	0.0	0.0	2.188	4.300	2.188
36	INSULATION	NOZ STA 4 - 5	80.492	11978.383	0.0	0.0	4.203	5.337	4.203
35	BACKUP		38.166	11978.813	0.0	0.0	2.330	4.614	2.330
34	LINER		42.326	11978.004	0.0	0.0	1.871	3.723	1.871
33	VIRGIN		3.045	11978.918	0.0	0.0	0.531	1.021	0.531
32	CHAR		4.016	11978.532	0.0	0.0	0.112	0.226	0.112
31	EXPENDED		30.265	11977.695	0.0	0.0	1.226	2.476	1.226
42	INSULATION	NOZ STA 5 - 6	54.053	11983.645	0.0	0.0	3.272	[illegible]	3.272
41	BACKUP		12.583	11983.340	0.0	0.0	1.919	[illegible]	1.919
40	LINER		41.470	11983.742	0.0	0.0	1.353	2.311	1.353
39	VIRGIN		29.586	11983.676	0.0	0.0	0.409	0.746	0.409
37	EXPENDED		11.684	11983.918	0.0	0.0	0.944	1.566	0.944

HARDWARE TEST CASE NO. 1

MASS PROPERTIES SUBROUTINE OUTPUT

COMPONENT IDENTIFICATION NUMBER AND DEFINITION			WEIGHT (POUNDS)	CENTER OF GRAVITY (INCHES)			MOMENT OF INERTIA (SLUG-FEET**2)		
ID. NUMBER	DEFINITION			LONG.	LAT.	VERT.	PITCH	ROLL	YAW
60	INSULATION	NOZ STA 6 - 7	8.001	11988.773	0.0	0.0	0.299	0.592	0.299
59	BACKUP		1.129	11988.809	0.0	0.0	0.157	0.311	0.157
58	LINER		6.872	11988.781	0.0	0.0	0.142	0.281	0.142
57	VIRGIN		4.381	11988.711	0.0	0.0	0.041	0.081	0.041
55	EXPENDED		2.491	11988.930	0.0	0.0	0.102	0.200	0.102
66	INSULATION	NOZ STA 7 - 8	71.169	11996.844	0.0	0.0	4.834	7.262	4.834
65	BACKUP		17.608	11997.195	0.0	0.0	0.213	0.512	0.213
64	LINER		53.561	11996.730	0.0	0.0	4.621	6.649	4.621
63	VIRGIN		3.842	11995.434	0.0	0.0	0.144	0.118	0.144
62	CHAR		25.936	11997.211	0.0	0.0	0.554	0.835	0.554
61	EXPENDED		23.783	11996.422	0.0	0.0	3.920	5.697	3.920
72	INSULATION	NOZ STA 8 - 14	62.207	12010.340	0.0	0.0	10.968	19.117	10.968
71	BACKUP		19.139	12010.348	0.0	0.0	0.703	1.205	0.703
70	LINER		43.068	12010.344	0.0	0.0	10.265	17.912	10.265
69	VIRGIN		1.894	12009.770	0.0	0.0	-0.008	0.117	-0.008
68	CHAR		24.437	12010.316	0.0	0.0	0.751	1.467	0.751
67	EXPENDED		16.738	12010.461	0.0	0.0	9.522	16.328	9.522
78	INSULATION	NOZ STA 14 - 15	61.396	12022.027	0.0	0.0	20.803	37.945	20.803
77	BACKUP		22.123	12022.063	0.0	0.0	0.982	2.009	0.982
76	LINER		39.273	12022.016	0.0	0.0	19.821	35.936	19.821
75	VIRGIN		1.633	12023.203	0.0	0.0	0.101	0.145	0.101
74	CHAR		22.582	12021.906	0.0	0.0	1.079	1.973	1.079
73	EXPENDED		15.058	12022.055	0.0	0.0	18.641	33.817	18.641

HARDWARE TEST CASE NO. 1

MASS PROPERTIES SUBROUTINE OUTPUT

COMPONENT IDENTIFICATION NUMBER AND DEFINITION		WEIGHT (POUNDS)	CENTER OF GRAVITY (INCHES)			MOMENT OF INERTIA (SLUG-FEET**2)		
ID. NUMBER	DEFINITION		LONG.	LAT.	VERT.	PITCH	ROLL	YAW
124	NOZZLE STRUCTURE TOTAL	553.841	11990.348	0.0	0.0	58.001	88.094	58.001
79	STRUCTURAL SHELL NOZ STA 1 - 2	151.121	11991.199	0.0	0.0	4.925	8.195	4.925
83	STRUCTURAL SHELL NOZ STA 7 - 12	41.533	11995.230	0.0	0.0	1.284	1.615	1.284
84	STRUCTURAL SHELL NOZ STA 12 - 15	19.195	12015.078	0.0	0.0	0.665	1.452	0.665
109	STRUCTURAL RINGS AND EXTENSIONS	312.408	11988.074	0.0	0.0	46.688	75.569	46.688
98	FLANGE	35.010	12000.254	0.0	0.0	2.789	5.577	2.789
102	MOVABLE EXTENSION	53.949	11985.598	0.0	0.0	21.428	34.721	21.428
103	EXIT RING	36.906	12005.598	0.0	0.0	4.876	9.739	4.876
105	FORWARD END RING	100.989	11982.566	0.0	0.0	6.327	12.462	6.327
106	AFT END RING	85.554	11983.625	0.0	0.0	6.603	13.070	6.603
52	FLEXIBLE BEARING	29.585	11983.031	0.0	0.0	0.634	1.264	0.634
51	METAL SHIMS	27.138	11983.031	0.0	0.0	0.582	1.160	0.582
50	RUBBER SHIMS	2.447	11983.031	0.0	0.0	0.052	0.105	0.052
121	MOVABLE NOZZLE ACTUATION SYSTEM	155.025	12001.785	0.0	0.0	5.197	10.234	5.197
122	EXPENDED	17.554	12001.785	0.0	0.0	0.588	1.159	0.588
123	UNEXPENDED	137.471	12001.785	0.0	0.0	4.609	9.075	4.609
162	TMC ASSEMBLY	438.554	11975.328	0.0	0.0	0.002	0.002	0.002
163	TMC POWER SUPPLY	13.927	12002.227	0.0	0.0	0.000	0.000	0.000
155	CASE FLANGE MATING WITH NOZZLE (NOT PART OF TOTAL SYSTEM WEIGHT)	97.004	11999.773	0.0	0.0	3.299	6.598	3.299
166	TOTAL MOVABLE ABOUT PIVOT	1130.602	11985.816	0.0	0.0	134.847	153.897	134.847
164	TMC ASSEMBLY ABOUT PIVOT	438.554	11975.328	0.0	0.0	0.003	0.002	0.003
165	MOVEABLE NOZZLE ABOUT PIVOT	692.047	11992.473	0.0	0.0	117.813	153.895	117.813

HARDWARE TEST CASE NO. 1

MASS PROPERTIES SUBROUTINE OUTPUT

COMPONENT IDENTIFICATION NUMBER AND DEFINITION		WEIGHT (POUNDS)	CENTER OF GRAVITY (INCHES)			MOMENT OF INERTIA (SLUG-FEET**2)		
ID. NUMBER	DEFINITION		LONG.	LAT.	VERT.	PITCH	ROLL	YAW
128	TOTAL INSULATION	507.239	11993.188	0.0	0.0	78.983	98.357	78.983
129	UNEXPENDED	351.184	11994.133	0.0	0.0	34.146	32.500	34.146
132	EXPENDED	156.055	11991.063	0.0	0.0	44.617	65.857	44.617
133	TOTAL STRUCTURE	553.841	11990.344	0.0	0.0	58.001	88.094	58.001
134	MOVABLE PORTION	692.047	11992.473	0.0	0.0	117.812	153.895	117.812
135	INSULATION	409.891	11993.684	0.0	0.0	75.421	92.642	75.421
136	EXPENDED	131.748	11994.070	0.0	0.0	43.674	64.383	43.674
137	UNEXPENDED	278.144	11994.918	0.0	0.0	31.461	28.259	31.461
138	STRUCTURE	282.156	11990.719	0.0	0.0	42.074	61.253	42.074
139	FIXED PORTION	369.033	11990.254	0.0	0.0	19.350	32.557	19.350
140	INSULATION	97.348	11991.059	0.0	0.0	3.423	5.716	3.423
141	EXPENDED	24.307	11991.023	0.0	0.0	0.941	1.474	0.941
142	UNEXPENDED	73.041	11991.086	0.0	0.0	2.482	4.241	2.482
143	STRUCTURE	271.685	11989.973	0.0	0.0	15.909	26.841	15.909

CTINP INPUT

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L7046 +3
L7100 +0 +35 +70
L7400 +56800 +56800 +56800
L7600 +56800 +56800 +56800
L7700 +225 +225 +225
L0 +1 +1
L4 +1 +2 +1 +1
L11 +72.806
L14 +25
L16 +52.56
L18 +24.6 +70 +450 +3 +65.5
T HARDWARE TEST CASE NO. 2
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HARDWARE TEST CASE NO. 2

STANDARD METHOD - LITVC SUBROUTINE
INJECTANT REQUIREMENTS

INPUT PARAMETERS

	LNLZ	DISTANCE FROM FORWARD FACE OF CASE FLANGE TO NOZZLE EXIT PLANE	32.0562	IN
L 685	LINJ	DISTANCE FROM NOZZLE THROAT TO INJECTION PORT	26.2800	IN
L 16	LNZ	DISTANCE FROM NOZZLE THROAT TO EXIT PLANE	52.5606	IN
L 23	XNF	DISTANCE FROM MISSLE REFERENCE STATION TO NOZZLE FLANGE	1000.0000	FT
L 7002	XE	DISTANCE FROM BODY STATION REF. STATION TO NOZZLE GIMBAL STATION	1000.0000	FT
L 7000	IV	TOTAL VEHICLE VACUUM THRUST IMPULSE	0.39759950E 07	LBF-SEC
L 2023	NQUADU	NO. OF QUADRANTS BEING UTLIZIED	4.0000	- -
L 14	ALPHAVG	NOZZLE HALF-ANGLE FROM INJECTION STATION TO NOZZLE EXIT	25.0000	DEG
L 2025	BETA-Q	ANGLE SPANNED BY INJECTION PORTS PER QUADRANT	75.0000	DEG
L 3232	KONE	EMPIRICAL CONSTANT TO DETERMINE UNEXPENDABLE INJECTANT	0.0300	- -
L 3233	KTWO	EMPIRICAL CONSTANT TO DETERMINE INJECTANT TOTAL REQUIREMENTS	0.0300	- -
L 3234	KTRI	EMPIRICAL CONSTANT TO DETERMINE INJECTANT TOTAL REQUIREMENTS	0.1000	- -
L 2022	TYPINJ	TYPE OF INJECTANT UTILIZED - N2O4	4.	- -
	RHOINJ	DENSITY OF INJECTANT	89.0000	LBM/FT**3

OUTPUT PARAMETERS

IF	CONTROL THRUST IMPULSE	0.0	LBF-SEC
IPAUG	ADDITIONAL IMPULSE DUE TO THRUST AUGMENTATION	0.0	LBF-SEC
KF	THRUST AUGMENTATION IMPULSE FACTOR	1.0000	- -
KDELT	RATIO OF CONTROL THRUST IMPULSE TO TOTAL VEHICLE VACUUM THRUST IMPULSE	0.0	- -
WDOTSQ	MAX. INJECTANT FLOW RATE PER QUADRANT	0.0	LBM/SEC
WLDC	INJECTANT REQUIRED FOR THE MAXIMUM TVC DUTY CYCLE	0.0	LBM
WLONE	UNEXPENDABLE INJECTANT - ALLOWANCE FOR EXPULSION EFFICIENCY	0.0	LBM
WLTWO	ALLOWANCE FOR SYSTEM ERRORS, MOTOR AND LITVC PERFORMANCE TOLERANCES	0.0	LBM
WLTRI	ALLOWANCE FOR ULLAGE AND MANIFOLDS, INJECTOR LEAKAGE	0.0	LBM
WL	TOTAL INJECTANT REQUIRED	0.0	LBM
WDTGPX	MAX. INJECTANT FLOW RATE (OBLIQUE ANGLE)	0.0	LBM/SEC

HARDWARE TEST CASE NO. 2

STANDARD METHOD - LITVC SUBROUTINE
INJECTANT REQUIREMENTS

TABULAR TIME-HISTORY OUTPUT FUNCTIONS

T	XCG	WDOTP	FCV	DEL-P	DEL-Y	KX	FS-P/FPV	FS-Y/FPV	FS	WDOTS	DELTFP
STAGE TIME	VEHICLE CENTER OF GRAVITY	PRIMARY MOTOR FLOW RATE	PRIMARY MOTOR VACUUM THRUST	PITCH TVC DEFLECTION	YAW TVC DEFLECTION	FORCE TRANSLATION FACTOR	RATIO OF PITCH TO AXIAL THRUST	RATIO OF YAW TO AXIAL THRUST	TOTAL SIDE FORCE GENERATED	SECONDARY INJECTION FLOW RATE	THRUST AUGMENTATION ATTRIBUTED TO LIQUID
SEC	FT	LBM/SEC	LBF	DEG	DEG	- -	- -	- -	LBF	LBM/SEC	LBF
0.0	0.0	225.0000	0.568000E 05	0.0	0.0	0.9991	0.0	0.0	0.0	0.0	0.0
35.000	0.0	225.0000	0.568000E 05	0.0	0.0	0.9991	0.0	0.0	0.0	0.0	0.0
70.000	0.0	225.0000	0.568000E 05	0.0	0.0	0.9991	0.0	0.0	0.0	0.0	0.0

HARDWARE TEST CASE NO. 2

LITVC ACTUATION AND PRESSURIZATION SUBROUTINE

INPUT PARAMETERS

L2040	0.	INJECTANT NOT USED AS HYDRAULIC FLUID	
L2041	0.	TYPE PRESSURIZATION	- MINIMUM WEIGHT SYSTEM
L2042	0.	TYPE ACTUATION	- MINIMUM WEIGHT SYSTEM
L2044	0.	INJECTANT TANK SHAPE	- NOT GIVEN
L2043	0.	COLD GAS TANK SHAPE	- NOT GIVEN
L2045	1.	TANK MATERIAL	- STEEL
L2022	4.	INJECTANT	- N2O4

INPUT PARAMETERS FROM OTHER SUBROUTINES

DELTA	MAXIMUM VECTOR ANGLE	3.00	DEG
DELCCT	THRUST VECTOR SLEW RATE	20.00	DEG/SEC
TA	ACTION TIME	70.00	SEC
BD	CASE DIAMETER	65.50	IN
NPV	NUMBER OF PINTLE VALVES PER QUADRANT	1.	- -
WDOTSQ	INJECTANT FLOW RATE PER QUADRANT	0.0	LB/SEC
WDOTSMAX	MAXIMUM INJECTANT FLOW RATE	0.0	LB/SEC
EPSINJ	EXPANSION RATIO AT POINT OF INJECTANT	10.40	- -
INP	INTEGRAL OF PITCH RATE	90.00	DEG
INY	INTEGRAL OF YAW RATE	90.00	DEG
WL	TOTAL WEIGHT OF USABLE INJECTANT	0.0	LB
DTINT	DIAMETER OF NOZZLE THROAT (INITIAL)	9.63	IN

OUTPUT DATA

TYPE ACTUATION - ELECTRO-MECHANICAL
TYPE PRESSURIZATION - WARM GAS
INJECTANT TANK SHAPE - TOROIDAL
COLD GAS TANK SHAPE - NOT GIVEN

WTACTL	TOTAL WEIGHT OF SELECTED SYSTEM	18.66	LB
	WARM GAS MOTOR PUMP + WARM GAS PRESSURIZATION	20.43	LB
	WARM GAS MOTOR PUMP - WARM GAS PRESSURIZATION	20.93	LB
	ELECTRIC MOTOR PUMP + WARM GAS PRESSURIZATION	21.66	LB
	COLD GAS BLOWDOWN - COLD GAS PRESSURIZATION	28.41	LB
	WARM GAS BLOWDOWN - WARM GAS PRESSURIZATION	36.70	LB
	WARM GAS BLOWDOWN + WARM GAS PRESSURIZATION	40.70	LB

HARDWARE TEST CASE NO. 2

LITVC ACTUATION AND PRESSURIZATION SUBROUTINE

COMPUTED COMPONENT WEIGHTS - WARM GAS PRESSURIZATION

WL	TOTAL WEIGHT OF INJECTANT ON BOARD	0.0	LB
WPV	WEIGHT OF INJECTOR VALVES	2.400	LB
WT	WEIGHT OF SPHERICAL INJECTANT TANK	0.0	LB
WTORTK	WEIGHT OF TORODIAL INJECTANT TANK	0.251	LB
WHGGC	WEIGHT OF WARM GAS GENERATOR	0.500	LB
WHGRV	WEIGHT OF HOT GAS RELIEF VALVE	0.250	LB
WITF	WEIGHT OF INJECTANT TUBING AND FITTINGS	1.831	LB
WGTF	WEIGHT OF WARM GAS TUBING AND FITTINGS	1.070	LB
WPT	WEIGHT OF PRESSURE TRANSDUCERS	1.000	LB

COMPUTED VARIABLES - COMMON

PI	INJECTANT PRESSURE	449.44	LB/IN**2
WDOTSV	INJECTANT FLOW RATE PER VALVE	0.0	LB/SEC
WDTH2O	WATER FLOW EQUIVALENT TO INJECTANT FLOW	0.0	LB/SEC
DP	DIAMETER OF PINTLE CAVITY	0.0	IN
XP	MAXIMUM TRAVEL OF PINTLE VALVE	0.0	IN
QPY	TOTAL HYDRAULIC FLOW	0.0	IN**3/SEC
QTB	TOTAL HYDRAULIC FLOW FOR BLOWDOWN	1.600	IN**3/SEC
QBC	HYDRAULIC FLOW FOR BLOWDOWN	0.0	IN**3/SEC
QTL	TOTAL SERVO LEAKAGE	1.600	IN**3/SEC
WOC	WEIGHT OF OIL IN HYDRAULIC CYLINDERS	0.0	LB
WOCB	WEIGHT OF OIL IN CYLINDERS (BLOWDOWN)	0.0	LB
LL	LENGTH OF HYDRAULIC LINES	411.549	IN
LLIL	LENGTH OF INJECTANT LINES	205.774	IN
IDL	INSIDE DIAMETER OF INJECTANT TUBING	0.0	IN
ODLT	OUTSIDE DIAMETER OF INJECTANT TUBING	0.250	IN
TL	WALL THICKNESS OF INJECTANT TUBING	0.020	IN
KK	CONSTANT USED TO COMPUTE WALL THICKNESS	0.640	- -
VOLEX	VOLUME OF HYDRAULIC OIL EXPENDED FOR BLOWDOWN	133.760	IN**3
VT	VOLUME OF INJECTANT TANK	0.0	IN**3
NT	NUMBER OF SPHERICAL INJECTANT TANKS	1.	- -
RSN	RADIUS OF SPHERICAL INJECTANT TANKS	0.0	IN
RT	MINOR RADIUS OF TORODIAL INJECTANT TANK	31.440	IN
TIT	WALL THICKNESS OF SPHERICAL INJECTANT TANK	0.030	IN
TTK	WALL THICKNESS OF TORODIAL INJECTANT TANK	0.046	IN
HP	HYDRAULIC HORSEPOWER	0.0	HP

ADDITIONAL COMPUTED PARAMETERS

WDTWGP	FLOW RATE OF GAS GENERATOR FOR WGP	0.0	LB/SEC
HPG	GAS HORSEPOWER	0.0	HP
SIGMA	MASS FRACTION OF GAS GENERATOR	0.050	- -
WHGG	WEIGHT OF GAS GENERATOR GRAIN	0.0	LB
KKHG	CONSTANT USED TO COMPUTE WALL THICKNESS OF WARM GAS LINES	0.852	- -
LGT	LENGTH OF WARM GAS LINES	102.89	IN
IDG	INSIDE DIAMETER OF WARM GAS LINES	0.0	IN
ODG	OUTSIDE DIAMETER OF WARM GAS LINES	0.250	IN
TG	WALL THICKNESS OF WARM GAS LINES	0.020	IN

HARDWARE TEST CASE NO. 2

LITVC ACTUATION AND PRESSURIZATION SUBROUTINE

COMPUTED COMPONENT WEIGHTS - ELECTRO-MECHANICAL

WEMI	WEIGHT OF ELECTROMECHANICAL INJECTORS	2.40	LB
WEC	WEIGHT OF ELECTRIC CABLE	4.12	LB
WB	WEIGHT OF BATTERY	2.00	LB

ADDITIONAL COMPUTED PARAMETERS

LEC	LENGTH OF ELECTRIC CABLE	205.77	IN

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THE FCLLOWING ERRORS OCCURED IN THE LITVC ACTUATICN CALCULATICNS

            TOROIDAL TANKS WILL NCT FIT IN THE SPECIFIEC
            ENVELOPE.
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CTINP INPUT

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L7C46 +3
L71CC +0 +35 +70
L74CC +56800 +56800 +5680C
L760C +56800 +56800 +56800
L77CC +225 +225 +225
L0 +1 +2
L3 +1 +1 +2 +1 +1
L11 +72.606
L14 +25
L16 +52.56
L18 +24.6 +70 +450 +3 +65.5
L2000 +4 +1.9 +1 +2 +3 +3 +2 +2 +3
T HARDWARE TEST CASE NO. 3
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HARDWARE TEST CASE NO. 3

MCT GAS VALVE SUBROUTINE

PINTLE VALVE

MANDATORY AND OPTIONAL INPUT PARAMETERS

L	2000	VAL 4	NONERODING PINTLE, SUPERSONIC INJECTION		
L	2002	AL1	PRESSURE BALANCED PINTLE		
L	2003	AT2	REVERSE ACTUATOR		
L	2004	BM3	PINTLE BALANCED WITH PINTLE TIP PRESSURE		
L	21	DEL-HE	INPUT MAX VECTOR ANGLE EXPECTED, DESIGN LIMIT	3.000000	DEG
L	2467	DN2	AVERAGE NOZZLE THROAT DIA.		
L	2005	EC3	CONTOUR EXIT CONE (AVERAGE ANGLE)		
L	2001	ETAV	VALVE CYCLIC RATE	1.900000	CPS
L	2008	MM3	LEG MOUNTED PINTLE VALVE		
L	2497	NV	NUMBER OF VALVES	4.000000	
L	2006	PT2	SEATING TYPE PINTLE		
L	2007	SO2	4 WAY SERVO ACTUATOR		
L	2511	CHG2	CONSTANT LOCATING TRUE SIDE FORCE WITH RESPECT TO INJECTION PORT	1.000000	
L	2513	CHG4	CONSTANT LOCATING APPROX. VALVE DUCT INLET	0.375000	
L	2514	CHG5	RATIO OF VALVE ENVELOPE TO VALVE DIAMETER	4.000000	
L	2517	CHG8	RATIO OF DO TO DDIP	1.200000	
L	2524	CHG15	THRUST AUGMENTATION FACTOR	0.402322	
L	2526	CHG19	PRESSURE CONSTANT	1.000000	
L	2535	CHG26	EMPIRICAL CONSTANT USED TO ADJUST CALCULATED DATA TO TEST DATA	1.000000	
L	2536	CHG27	EMPIRICAL CONSTANT DEFINING VALVE ORIFICE EXPANSION CONE	1.000000	
L	2537	CHG28	RATIO OF TOTAL PRESSURE AT ORIFICE TO TOTAL PRESSURE AT SONIC VALVE AREA	1.000000	
L	2538	CHG29	RATIO OF TOTAL PRESSURE AT SONIC VALVE AREA TO CHAMBER PRESSURE	1.000000	
L	2539	CHG30	CONSTANT USED TO ADJUST VALVE THEORETICAL STROKE	1.000000	
L	2540	CHG31	RATIO OF PINTLE TIP RADIUS TO PINTLE DIA.	0.100000	
L	2541	CHG32	OVERSTROKE MULTIPLIER	1.000000	
L	2542	CHG33	SLOPE MULTIPLIER FOR PTP/PCV RATIO	1.000000	
L	2543	CHG34A	ACTUATOR FORCE MULTIPLIER	2.099999	
L	2544	CHG34B	ACTUATOR FORCE MULTIPLIER	1.099999	
L	2545	CHG36	RATIO OF SHAFT AREA TO PINTLE TIP	1.000000	
L	2546	CHG37	O-RING COMPRESSION FACTOR	1.000000	
L	2547	CHG38	O-RING PRESSURE FACTOR	1.000000	
L	2548	CHG39	PINTLE FRICTION MULTIPLIER	20.000000	
L	2551	CHG42	AREA MULTIPLIER-CHAMBER PRESSURE BALANCED PINTLE	1.000000	
L	2552	CHG43	AREA MULTIPLIER-TIP PRESSURE BALANCED PINTLE, REVERSE ACTUATOR	1.000000	
L	2553	CHG44	LENGTH CONSTANT FOR REFRACTORY SHELL	0.0	IN
L	2554	CHG45	PINTLE SHELL SHORTNESS LIMIT	0.200000	
L	2555	CHG46	STROKE MULTIPLIER	1.099999	
L	2556	CHG47	GLAND LENGTH MULTIPLIER	3.000000	
L	2557	CHG48	ACTUATOR STRUCTURE CONSTANT	0.400000	IN
L	2558	CHG49	LENGTH CONSTANT FOR LVDT ENVELOPE	1.000000	
L	2559	CHG50	HOUSING THICKNESS CONSTANT	0.0	IN
L	2560	CHG51	FLANGE HEIGHT MULTIPLIER	1.000000	
L	2561	CHG52	CAP THICKNESS CONSTANT	0.100000	IN
L	2562	CHG53	STRENGTH OF SHAFT MATERIAL	90000.000000	LB/SQ IN
L	2563	CHG54	SHAFT DIAMETER LIMIT	0.500000	IN
L	2565	CHG56	SPLITLINE LENGTH MULTIPLIER	1.299999	

HARDWARE TEST CASE NO. 3

HOT GAS VALVE SUBROUTINE

PINTLE VALVE

MANDATORY AND OPTIONAL INPUT PARAMETERS

L	2566	CHG57	SPLITLINE LENGTH CONSTANT FOR SCRAPER	0.550000	
L	2567	CHG58	PINTLE BODY LENGTH CONSTANT	2.000000	
L	2568	CHG59	ACTUATOR SHAFT LENGTH MULTIPLIER	1.500000	
L	2569	CHG60	O-RING GROOVE FACTOR FOR SHAFT	0.500000	
L	2570	CHG61	RUBBER THICKNESS CONSTANT	0.250000	IN
L	2572	CHG63	ORIFICE LENGTH MULTIPLIER	1.000000	
L	2576	CHG67	ITERATION LIMIT ON AL - PERCENT	1.000000	
L	2577	CHG68	ITERATION LIMIT ON ETA-A - PERCENT	0.500000	
L	2578	CHG65	BOLT CIRCLE LOCATOR	0.300000	IN
L	2579	CHG70	ITERATION LIMIT ON XMACHI - PERCENT	1.000000	
L	2580	CHG71	ITERATION LIMIT ON AV/ASTARP - PERCENT	1.000000	
L	2475	GAMMAP	RATIO OF SPECIFIC HEATS FOR NOZZLE EXHAUST	1.179999	
L	2476	GAMMAS	RATIO OF SPECIFIC HEATS, VALVE GASES	1.179999	
L	2471	EPSV-N	INJECTION ANGLE BETWEEN THE VALVE C.L. AND THE UPSTREAM NOZZLE WALL	89.999939	DEG
L	2458	ALPHAS	VALVE ORIFICE EXIT ANGLE	3.000000	DEG
L	2463	CDV	VALVE FLOW COEFFICIENT	0.766000	
L	2473	ETA-NS	INJECTION PORT FLOW COEFFICIENT	0.960000	
L	2455	XMACHS	VALVE INJECTION MACH NUMBER	1.000000	
L	2464	CNS	SECONDARY NOZZLE FLOW COEFFICIENT	0.854000	
L	2466	CSTARS	CHARACTERISTIC VELOCITY, VALVE FLOW	5200.000000	FT/SEC
L	2465	CSTARP	CHARACTERISTIC VELOCITY, PRIMARY FLOW	5200.000000	FT/SEC
L	2483	REX/CSTARP	VALVE ORIFICE RADIUS DIVIDED BY NOZZLE THROAT DIA.	1.000000	
L	2477	GPRIME	EMPIRICAL CONSTANT	0.700000	
L	2462	CDP	SONIC DISCHARGE COEFFICIENT, PRIMARY NOZZLE	0.990000	
L	2009	AO	GEOMETRIC ORIFICE FLOW AREA	0.0	SQ IN
L	2496	N	PROPELLANT BURN RATE EXPONENT	0.300000	
L	2465	EDPT	PINTLE TIP EROSION RATE	0.025000	IN/SEC
L	2486	TF	GAS FLAME TEMP	6140.000000	DEG R
L	2494	TOP	FINAL BACKSIDE PINTLE TIP TEMP	1460.000000	DEG R
L	2490	TIP	INITIAL BACKSIDE PINTLE TIP TEMP	540.000000	DEG R
L	2492	TOH	FINAL HOUSING BACKSIDE TEMP	900.000000	DEG R
L	2466	TIH	INITIAL HOUSING BACKSIDE TEMP	540.000000	DEG R
L	2491	TOC	FINAL CAP BACKSIDE TEMP	660.000000	DEG R
L	2487	TIC	INITIAL CAP BACKSIDE TEMP	540.000000	DEG R
L	2493	TOL	FINAL LEG BACKSIDE TEMP	660.000000	DEG R
L	2489	TIL	INITIAL LEG BACKSIDE TEMP	540.000000	DEG R
L	2460	ALPHATIP1	THERMAL DIFFUSIVITY OF TUNGSTEN FOR PINTLE TIP SHELL	0.047486	SQ IN/SEC
L	2453	ALPHAHOUS	THERMAL DIFFUSIVITY OF SILICA CLOTH FOR VALVE HOUSING	0.000521	SQ IN/SEC
L	2451	ALPHACAP6	THERMAL DIFFUSIVITY OF V-44 FOR VALVE CAP	0.000214	SQ IN/SEC
L	2455	ALPHALEG5	THERMAL DIFFUSIVITY OF SILICA CLOTH FOR LEG INSULATION	0.000621	SQ IN/SEC
L	2457	ALPHALIN6	THERMAL DIFFUSIVITY OF CARBON CLOTH FOR DUCT INSULATION	0.0	SQ IN/SEC
L	2470	EPSD	AREA RATIO, DUCT TO VALVE ORIFICE	3.000000	
L	2472	ERREL	EROSION RATE LINER	0.010000	IN/SEC
L	2496	TFV	HOT GAS VALVE FLOW TIME	0.0	SEC
L	2484	ST	TENSILE STRENGTH OF DUCT SHELL	93000.000000	LB/SQ IN
L	2482	RHOSH	DENSITY OF DUCT SHELL MATERIAL	0.176000	LB/CU IN
L	2481	RHOLIN	DENSITY OF DUCT LINER MATERIAL	0.065200	LB/CU IN
L	2480	RHCC	APPROX. DENSITY OF COMPOSITE CLOSURE MATERIAL	0.100000	LB/CU IN

HARDWARE TEST CASE NO. 3

MCT GAS VALVE SUBROUTINE

PINTLE VALVE

INPUT PARAMETERS FROM OTHER SUBROUTINES

	NOZZLES				
L	11	ATAVG	AVERAGE NOZZLE THROAT AREA	72.605939	SQ IN
		CFV	THRUST COEFFICIENT CORRECTED TO ISP REFERENCE	1.824990	
		CFVIT	THRUST COEFFICIENT DETERMINED DURING ITERATION	1.824990	
L	15	DELTH	TURNBACK ANGLE	10.538636	DEG
L	10	DTAVG	AVERAGE NOZZLE THROAT DIA.	9.628056	IN
L	12	DTINT	INITIAL NOZZLE THROAT DIA.	9.628056	IN
		EPS11	NOZZLE EXPANSION RATIO AT STATION 11	10.401150	
L	666	EPS15	NOZZLE EXPANSION RATIO AT STATION 15	24.800003	
		LIN	DISTANCE FROM NOZZLE THROAT TO NOZZLE FLANGE	30.805878	IN
		LINJ	DISTANCE FROM NOZZLE THROAT TO INJECTION PORT CENTERLINE	26.279999	IN
		LNCZ	INPUT LENGTH OF NOZZLE FROM FORWARD FACE OF NOZZLE TO EXIT PLANE	29.306458	IN
L	16	LNZ	DISTANCE FROM NOZZLE THROAT TO NOZZLE EXIT PLANE	52.560577	IN
		M11	MACH NO. AT INJECTION PORT LOCATION	3.247619	
		R11	RADIUS OF NOZZLE AT INJECTION PORT LOCATION	15.525635	IN
L	668	R15	NOZZLE RADIUS AT STATION 15	23.973663	IN
L	14	THETAI	CONICAL NOZZLE HALF ANGLE OR CONTOUR NOZZLE INITIAL DIVERGENCE ANGLE	24.999985	DEG
		X11	AXIAL LENGTH FROM NOZZLE THROAT TO STATION 11	26.279999	IN
L	667	X15	AXIAL LENGTH FROM NOZZLE THROAT TO EXIT PLANE, STA. 15	52.560577	IN
L	421	XDCT6	NOZZLE THROAT EROSION RATE	0.0	ML/SEC
	TRAJECTORY				
L	7014	DEL-PM	MAX PITCH THRUST VECTOR DEFLECTION ANGLE FOR TVC DESIGN	0.0	DEG
L	7020	DEL-YM	MAX YAW THRUST VECTOR DEFLECTION ANGLE FOR TVC DESIGN	0.0	DEG
L	7012	ETAP	RATIO OF DELIVERED THRUST TO VACUUM THRUST AT DEL-PM	1.000000	
L	7018	ETAY	RATIO OF DELIVERED THRUST TO VACUUM THRUST AT DEL-YM	1.000000	
L	20	PCB	AVERAGE MOTOR CHAMBER PRESSURE	450.000000	LB/SQ IN
L	19	TA	MOTOR ACTION TIME	70.000000	SEC
L	2485	TB	TIME TO WEB BURNOUT	66.499985	SEC
		TM2	TIME AT WHICH DEL-M2 OCCURS	0.0	SEC
L	7001	IVT	INPUT TOTAL VEHICLE VACUUM THRUST IMPULSE	0.397600E 07	LB-SEC
L	7005	ISPVAC	INPUT VACUUM SPECIFIC IMPULSE	0.252444E 03	LB-SEC/LB
		XCGP	MOTOR CENTER OF GRAVITY LOCATION AT TIME OF DEL-PM	0.0	FT
		XCGY	MOTOR CENTER OF GRAVITY LOCATION AT TIME OF DEL-YM	0.0	FT
L	7002	XE	COMPUTED STAGE THRUST GIMBAL BODY STATION NUMBER	0.100000E 04	FT
L	23	XNF	DISTANCE FROM REFERENCE DATUM POINT TO NOZZLE FLANGE LOCATION	0.100000E 04	FT

HARDWARE TEST CASE NO. 3

MCT GAS VALVE SUBROUTINE

PINTLE VALVE

OUTPUT FROM SUBROUTINE

DELPM2	MAX PITCH VECTOR ANGLE BASED ON DELIVERED THRUST, (ADJUSTED)	0.0	DEG
DELYM2	MAX YAW VECTOR ANGLE BASED ON DELIVERED THRUST, (ADJUSTED)	0.0	DEG
DEL-M2	MAX OF DELPM2 AND DELYM2	0.0	DEG
DEL-M3	MAX OF DEL-M2 AND DEL-ME	3.000000	DEG
DSTARP	NOZZLE THROAT DIA. EMPLOYED FOR PERFORMANCE CAL.	9.628056	IN
ASTARP	PRIMARY NOZZLE FLOW AREA BASED ON DSTARP	72.805969	SQ IN
BETA2	ORIFICE REF. ANGLE NO. 1	86.999908	DEG
BETA3	ORIFICE REF. ANGLE NO. 2	92.999985	DEG
ETA-P	RATIO OF INJECTANT GAS TOTAL PRESSURE TO MAIN MOTOR PRESSURE	1.000000	
XNU	VARIABLE IN PREDICTION EQUATION	0.336498	
CFM	MOMENTUM THRUST COEFFICIENT PARALLEL TO VALVE C.L.	1.176948	
CFMN	MOMENTUM THRUST COEFFICIENT NORMAL TO VALVE C.L.	-0.000000	
TAUS	MODIFIED ISENTROPIC EXPONENT SECONDARY FLOW	0.644618	
TAUP	MODIFIED ISENTROPIC EXPONENT PRIMARY FLOW	0.644618	
OMEGA2	INTERACTION COEFFICIENT NO. 2	1.973135	
OMEGA1	INTERACTION COEFFICIENT NO. 1	1.136851	
OMEGA	COMBINED INTERACTION COEFFICIENT	1.892654	
ALPHAN3	CONTOUR EXIT CONE (AVERAGE ANGLE)	17.820251	DEG
CFIN	TOTAL INTERACTION FORCE COEFFICIENT NORMAL TO THE PRIMARY WALL	1.657385	
S/DSTARP	LENGTH FROM VALVE C.L. TO EXIT PLANE DIVIDED BY NOZZLE THROAT DIAMETER	2.991414	
REX/DSTARP	VALVE ORIFICE RADIUS DIVIDED BY NOZZLE THROAT DIA.	0.124271	
ETAPHI	INTERACTION FORCE RATIO TIMES NOZZLE EXIT CONE TANGENTIAL ANGLE	37.601044	DEG
ETA-A	RATIO OF ASTARS AND ASTARP	0.047319	
CFS	VALVE SIDE THRUST COEFFICIENT	2.155972	
CFX	VALVE AXIAL THRUST COEFFICIENT	0.867396	
ASTARS	VALVE SONIC FLOW AREA	3.445076	SQ IN
AO	GEOMETRIC ORIFICE FLOW AREA	4.497488	SQ IN
DO	VALVE ORIFICE DIAMETER	2.392985	IN
DP	PINTLE DIAMETER	3.070862	IN
RP	PINTLE CONTACT RADIUS	1.365961	IN
LMT	MAX THEORETICAL STROKE, PINTLE VALVE	0.631466	IN
LMF	MAX TOTAL STROKE-ABLATIVE PINTLE	0.0	IN

L/LMT	STROKE RATIO	0.0000	0.1000	0.2000	0.3000	0.4000	0.5000	0.6000	0.7000	0.8000	0.9000	1.0000	
L	VALVE STROKE	0.0	0.06	0.13	0.19	0.25	0.32	0.38	0.44	0.51	0.57	0.63	IN
AVGEO	ORIFICE AREA	0.0	0.41	0.83	1.26	1.65	2.14	2.59	3.06	3.53	4.01	4.50	SQ IN
AVLEOR	GEO VALVE AREA RATIO	0.0	0.0911	0.1842	0.2793	0.3704	0.4754	0.5764	0.6793	0.7842	0.8911	1.0000	
AV/AG	AERO VALVE AREA RATIO	0.0	0.0909	0.1832	0.2761	0.3695	0.4551	0.5455	0.6200	0.6853	0.7321	0.7660	
AV	AERO VALVE AREA	0.0	0.41	0.82	1.24	1.66	2.06	2.45	2.79	3.08	3.29	3.45	SQ IN
CUVPRIME	EXP VALVE FLOW COEFF	1.0000	0.9973	0.9945	0.9884	0.9817	0.9657	0.9465	0.9127	0.8738	0.8215	0.7660	
PCV	POD MOTOR PRESSURE	450.0	446.4	442.8	439.3	435.7	432.4	429.2	426.5	424.1	422.4	421.2	LB/SQ IN
PTP/PC	TIP PRESSURE RATIO	0.2086	0.2805	0.3536	0.4271	0.5010	0.5719	0.6403	0.6992	0.7509	0.7880	0.8148	
PTP	TIP PRESSURE	93.9	126.2	159.1	192.2	225.4	257.3	286.1	314.7	337.9	354.6	366.7	LB/SQ IN
PTPPR	TIP PRESSURE (PC VARY)	93.9	125.2	156.6	187.6	210.3	247.3	274.8	296.2	318.5	332.9	343.2	LB/SQ IN
PB/PCB	BALANCING PRESS. RATIO	0.0	0.0058	0.0266	0.0652	0.1256	0.2060	0.3051	0.4036	0.4931	0.5604	0.6110	
PB	BALANCING PRESSURE	0.0	2.6	11.9	29.3	56.5	92.7	137.3	181.6	221.9	252.2	275.0	LB/SQ IN
FTIP	PINTLE TIP FORCE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	LB
FEXT	EXTEND ACTUATOR FORCE	1400.	1642.	1834.	1962.	2011.	1976.	1864.	1719.	1560.	1469.	1382.	LB
FRET	RETRACT ACTUATOR FORCE	-129.	-372.	-564.	-692.	-741.	-706.	-594.	-449.	-310.	-199.	-112.	LB

HARDWARE TEST CASE NO. 3

HOT GAS VALVE SUBROUTINE

PINTLE VALVE

OUTPUT FROM SUBROUTINE

DELTA-TB	BURNING TIME EXTENSION RESULTING FROM VALVE OPERATION	0.000076	SEC
FAV2B	AVERAGE MOTOR THRUST OVER DELTA-TB	56800.000000	LBS
XI2	CALCULATED TOTAL VEHICLE VACUUM THRUST IMPULSE	3975998.000000	LB-SEC
XKTM	VACUUM THRUST TIME MULTIPLIER	1.000001	
XKFM	VACUUM THRUST MAGNITUDE MULTIPLIER	1.000000	
XKTW	PROPELLANT FLOW RATE MULTIPLIER	1.000001	
XKWP	PROPELLANT FLOW RATE MULTIPLIER	0.999999	
XISP2	CALCULATED VACUUM SPECIFIC IMPULSE	252.444504	LB SEC/LB
WI	TOTAL WEIGHT OF INJECTED GASES	0.0	LB
WP	INITIAL MOTOR PROPELLANT WEIGHT	15749.984375	LB
WSMI	MEAN VALVE FLOW RATE (PER VALVE)	9.592083	LB/SEC
AP	PINTLE TIP CROSS SECTIONAL AREA	7.406456	SQ IN
PF	PINTLE FRICTION	192.947937	LB
AFF	ACTUATOR FRICTION FORCE	384.496582	LB
ABF	PRESSURE BALANCING AREA ON PINTLE TIP	0.0	SQ IN
DAPR	ACTUATOR PISTON DIAMETER	0.0	IN
FAVP	MAX VALVE ACTUATOR FORCE	2011.464111	LB
XN2	DUTY CYCLE MULTIPLIER, PINTLE VALVE	0.210489	IN/DEG
XLTIP	LENGTH OF REFRACTORY PINTLE TIP	6.263998	IN
XLGL	O-RING GLAND LENGTH	0.724000	IN
XLACTWOF	ACTUATOR LENGTH W/O FEEDBACK	3.496612	IN
XLLVDT	FEEDBACK LENGTH	0.0	IN
XLACT	ACTUATOR LENGTH WITH FEEDBACK	0.0	IN
THOU	VALVE HOUSING THICKNESS	1.177273	IN
TCAP	ACTUATOR CAP INSULATION THICKNESS	1.311803	IN
XLGLP	GLAND LENGTH	0.724000	IN
XLSL	VALVE SPLIT-LINE LENGTH	2.094905	IN
DELLTIP	PINTLE AND ACTUATOR LENGTH DIFFERENCE	4.862291	IN
XLBODY	PINTLE BODY LENGTH	10.358903	IN
XLAS	ACTUATOR SHAFT LENGTH	2.482630	IN
XLTIPA	ABLATIVE VALVE RUBBER TIP LENGTH	0.0	IN
XLTOT	TOTAL VALVE ENVELOPE LENGTH	14.153336	IN
LD	DUCT LENGTH	0.0	IN
DD	DUCT INTERNAL DIAMETER	0.0	IN
TLIN	DUCT LINER THICKNESS	0.0	IN
TSH	DUCT SHELL THICKNESS	0.0	IN
XLO	ORIFICE LENGTH	0.0	IN
GPH	FLOW ANNULUS AROUND VALVE BODY	0.0	IN
TVH	VALVE HOUSING THICKNESS (OUTER)	0.0	IN
XLSHAFT	LENGTH FROM PINTLE TIP TO VALVE CENTERLINE	0.0	IN
RSHAFT	RADIUS TO VALVE FLANGE	0.0	IN
DSHAFT	SHAFT DIAMETER	0.0	IN
GLEG	GAP BETWEEN HOUSING AND LEG	0.101062	IN
DH	HYDRAULIC PASSAGE DIAMETER	0.125000	IN
XLLEG	LEG LENGTH	12.841533	IN
DLEG	LEG DIAMETER	0.151445	IN
TLEG	LEG INSULATION THICKNESS	2.061885	IN
DBC	VALVE BOLT CIRCLE DIA.	0.0	IN
RCYL	VALVE ENVELOPE RADIUS	7.088979	IN
DOIP	CUT OUT REQUIRED FOR ORIFICE INSTALLATION	2.871572	IN

HARDWARE TEST CASE NO. 3

HOT GAS VALVE SUBROUTINE

PINTLE VALVE

OUTPUT FROM SUBROUTINE

WTD	DUCT WEIGHT	0.0	LB
CGD	DUCT CENTER OF GRAVITY	0.0	FT
WTCBU	CASE BUILD UP WEIGHT	0.0	LB
CGCBL	CASE (NOZZLE) BUILD UP WEIGHT C.G. LOCATION	0.0	FT
WT-VAL	WEIGHT OF SELECTED VALVE (INCLUDING ACTUATOR)	31.104492	LB
CGV	VALVE CENTER OF GRAVITY LOCATION	1000.251953	FT
TOTSYS-WT	TOTAL SYSTEM WEIGHT	124.417969	LB

TIME DEPENDENT OUTPUT

TIME	DELTA	AV/ASTARP	FAV2	DELP2	DELY2	FVAC	CG
0.0	0.0	0.0	56800.000	0.0	0.0	56800.000	0.0
35.00000	0.0	0.0	56800.000	0.0	0.0	56800.000	0.0
70.00000	0.0	0.0	56800.000	0.0	0.0	56800.000	0.0

CTINP INPUT

```
L7C4C +3
L71CC +0 +35 +7C
L74CC +56600 +56800 +56800
L76CC +56800 +56800 +56800
L7700 +225 +225 +225
L0 +1 +3
L4 +1 +2 +1 +1
L11 +72.606
L14 +25
L16 +52.56
L18 +24.6 +70 +450 +3 +65.5
T HARDWARE TEST CASE NO. 4
```

HARDWARE TEST CASE NO. 4

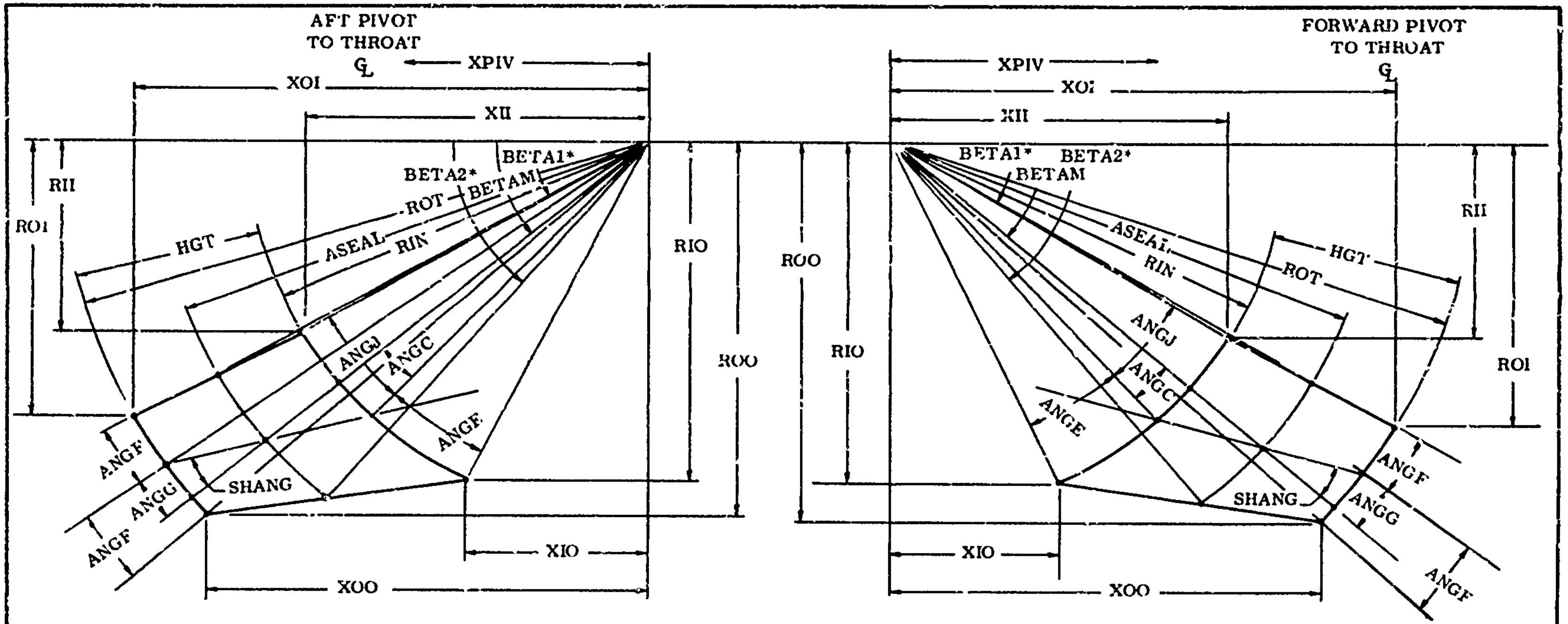
OUTPUT FROM JETTAB SUBROUTINE

TMAX 0.0	TNP 0.0	TNY 0.0	DELMAX 3.00	DP MAX 0.0	DY MAX 0.0	F 56800.00
AJT 78.67	TI 0.0	FAJT 7009.93	RJT 12.80	RS 0.85	DJT 2.81	TAERO 370.28
LBC 2.33	MB 67752.13	TFR 123.19	TFA 31.21	WJT 41.04	TG 274.22	LS 5.94
WT 44.83	TT 1298.89	LP 2.54	A 2.25	WTB 285.96	RTB 29.75	TC 0.04
I-A -42245.24						

HARDWARE TEST CASE NO. 4

OUTPUT FROM JETTAB SUBROUTINE
TIME DEPENDENT PARAMETERS

TIME	PITCH DECR.	YAW DECR.	TOTAL DECR.	FC	THETA P	THETA Y
0.0	0.0	0.0	0.0	56800.00	0.0	0.0
0.0	0.021250	0.0	0.021250	55592.99	60.00	0.0
70.00	0.0	0.0	0.0	56800.00	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0



ITEMS UNDERLINED ARE OPTIONAL INPUT

<u>TM</u> - THICKNESS OF EACH METAL SHIM

TMNO NUMBER OF METAL SHIMS

TR THICKNESS OF EACH RUBBER SHIM

TRNO NUMBER OF RUBBER SHIMS

<u>TMTR</u> - (TM)/(TR)

CHD - ASEAL (BETA2 - BETA1) RADIANS

RHT = HGT/CHD

*INITIAL VALUES OF BETA1 AND BETA2 ARE OPTIONAL INPUT. BETA1 DOES NOT CHANGE; HOWEVER, BETA2 AND THE AVERAGE OF BETA1 AND BETA2 (BETAM) ARE CHANGED BY THE ITERATION PROCEDURE.

SHANG IS THE ANGLE BETWEEN THE LINE JOINING THE CENTER OF THE MEAN SHIM TO THE PIVOT CENTER AND THE LINE JOINING THE CENTERS OF THE INNERMOST AND OUTERMOST ELASTOMER LAYERS.

PSHANG IS THE MAXIMUM VALUE OF SHANG WHICH OCCURS AT ONE OF THE EXTREME VECTORED POSITIONS.

EMSHNG IS THE MAXIMUM VALUE OF SHANG WHICH OCCURS AT THE OPPOSITE EXTREME POSITION.

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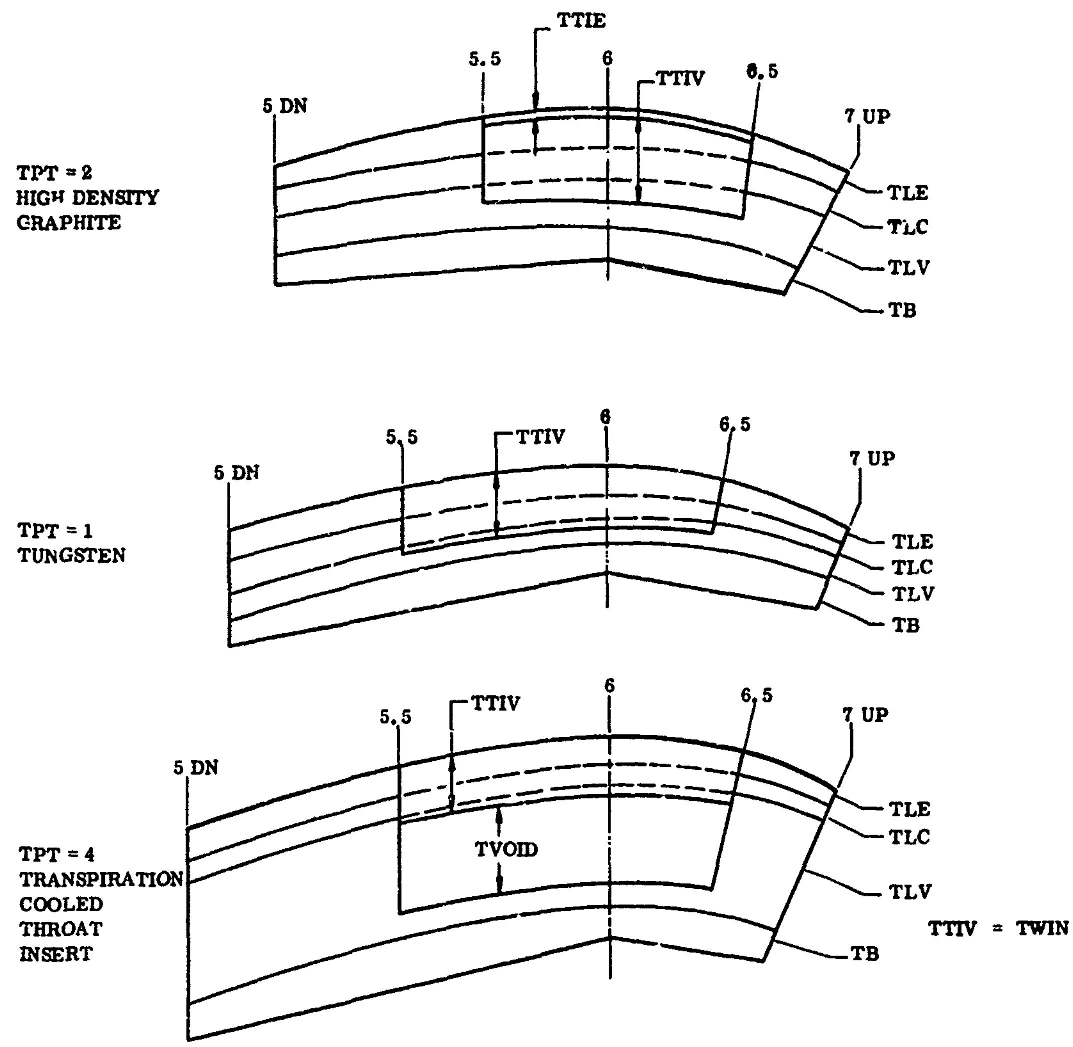
(U) Figure 2. Flexible Seal Geometry



THE LOCATION OF STATION 5.5 MAY BE SPECIFIED BY THE INPUT OF X5.5 OR EPS5.5 FOR TYPNOZ = 1, 5, 6 AND BY X5.5 FOR TYPNOZ = 2, 3, 4, 7.

THE LOCATION OF STATION 6.5 MAY BE SPECIFIED BY THE INPUT OF X6.5 OR EPS6.5 FOR ALL TYPNOZ.

THE OUTSIDE OF THE INSERT IS FORCED TO LIE IN THE TLV LAYER AT LEAST A DISTANCE CN 140 FROM THE INSIDE OF THE TLV LAYER. IF THE CALCULATED INSERT THICKNESS IS LESS THAN THE SUM OF TLE, TLC, AND CN 140 CALCULATED FOR THE MATERIAL OF SECTIONS 5 THRU 7 AT STATION 6 WITHOUT AN INSERT, THEN THE INSERT IS INCREASED IN THICKNEES THE REQUIRED AMOUNT. IF THE INSERT IS THICKER THAN TLE + TLC + TLV, THEN TLV IS INCREASED THE REQUIRED AMOUNT.

Figure 3. Throat Inserts

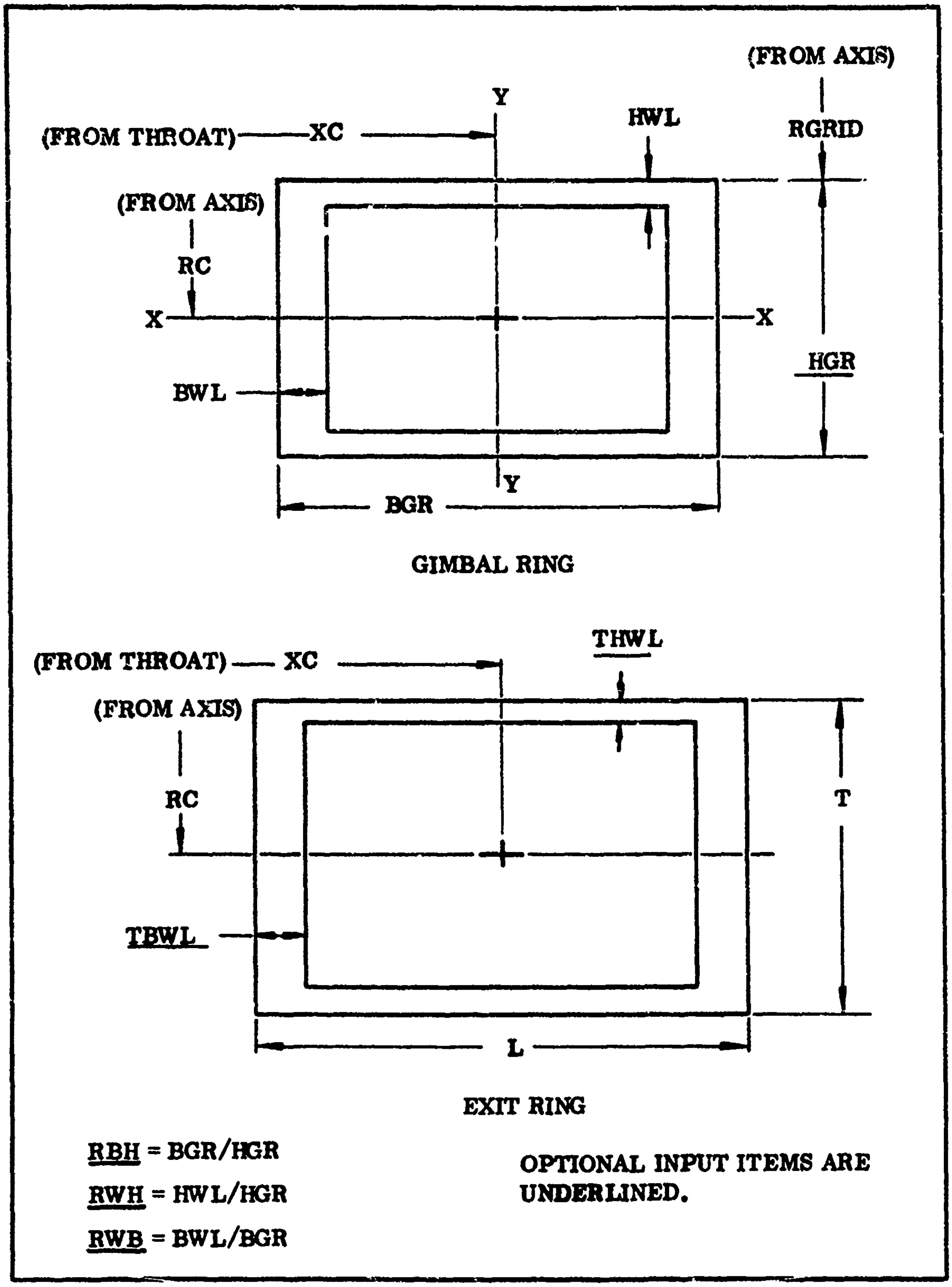


Figure 4. Gimbal Ring and Exit Ring Geometry

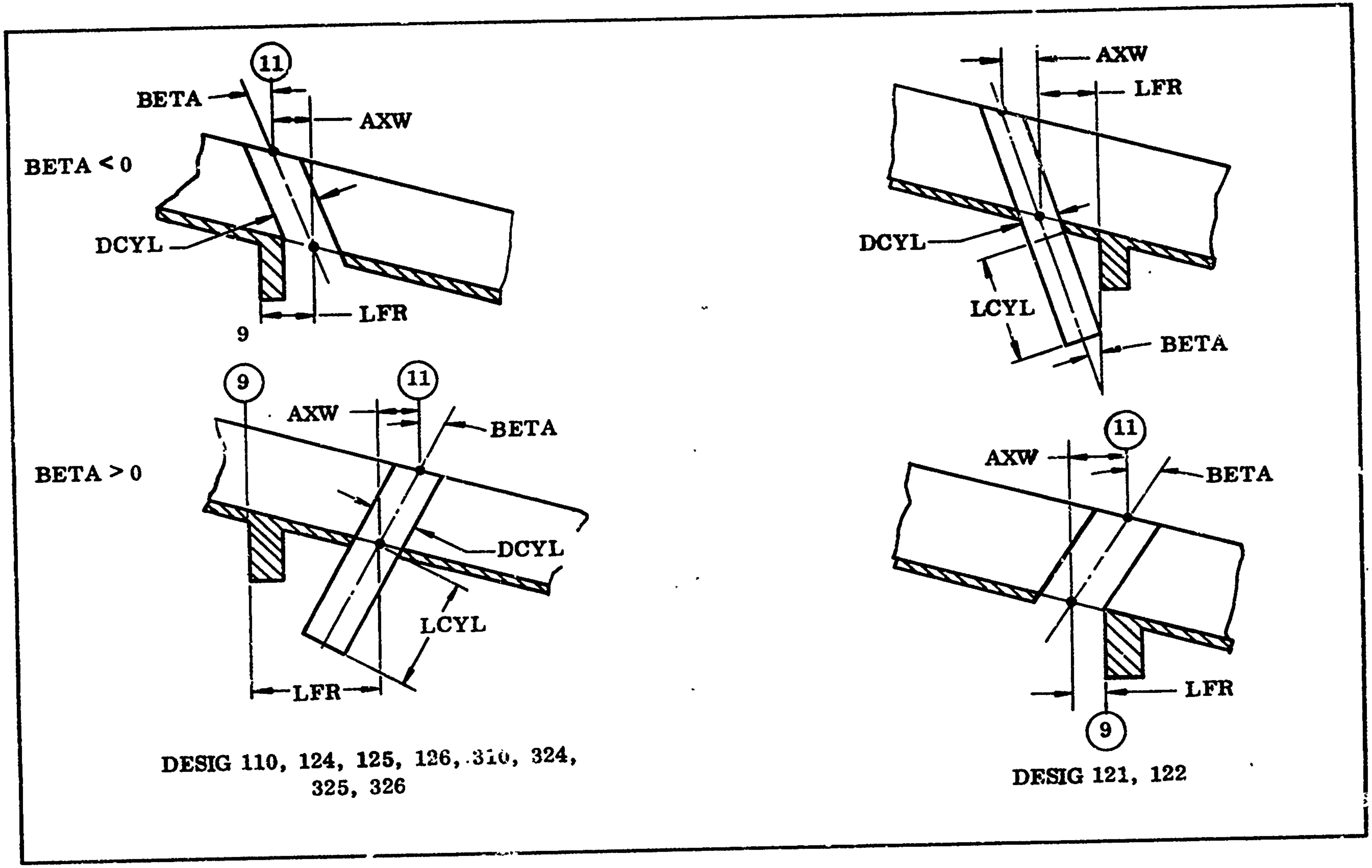


Figure 5. Injection Port Details

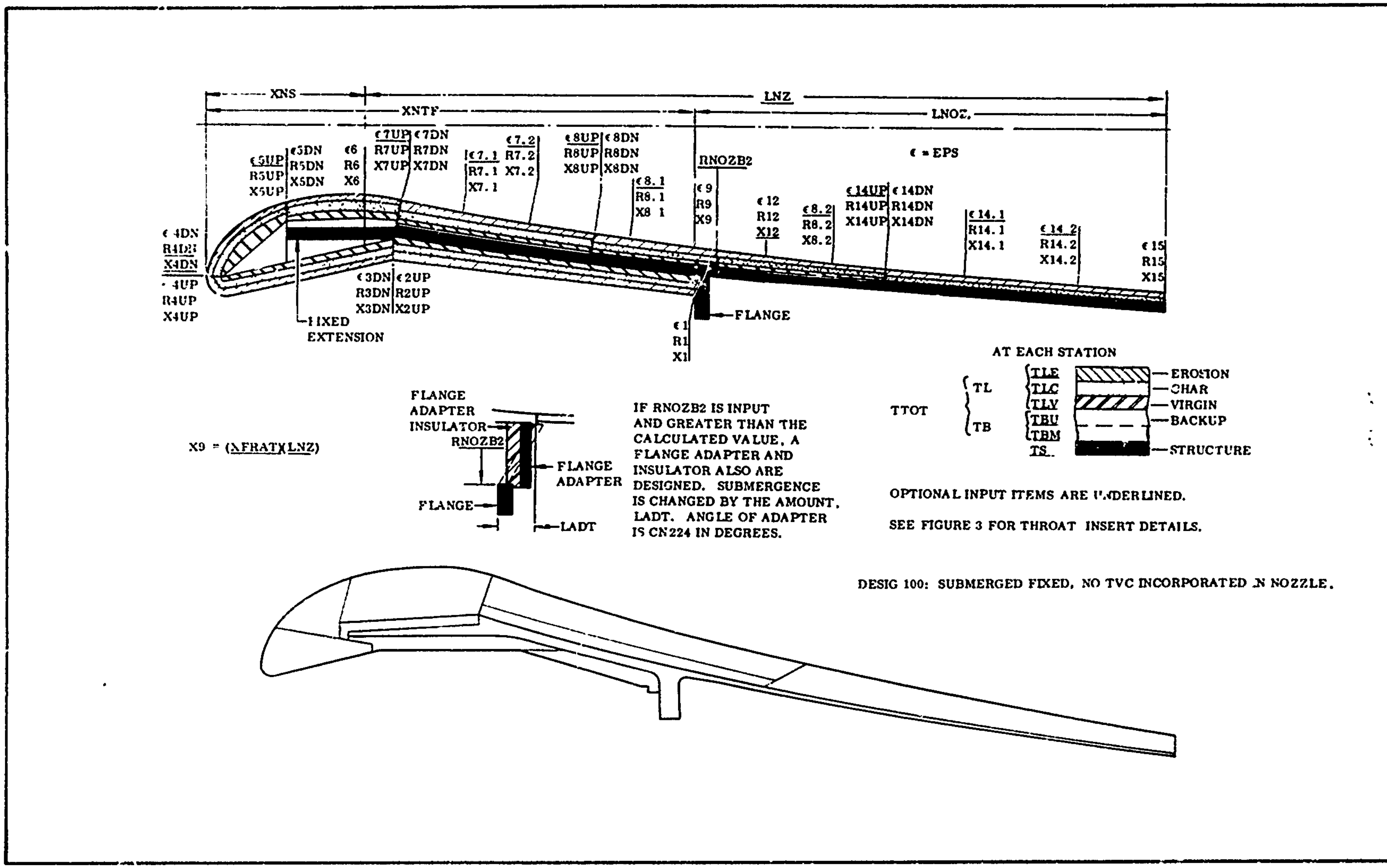


Figure 6. Nozzle DESIG 100 Diagram

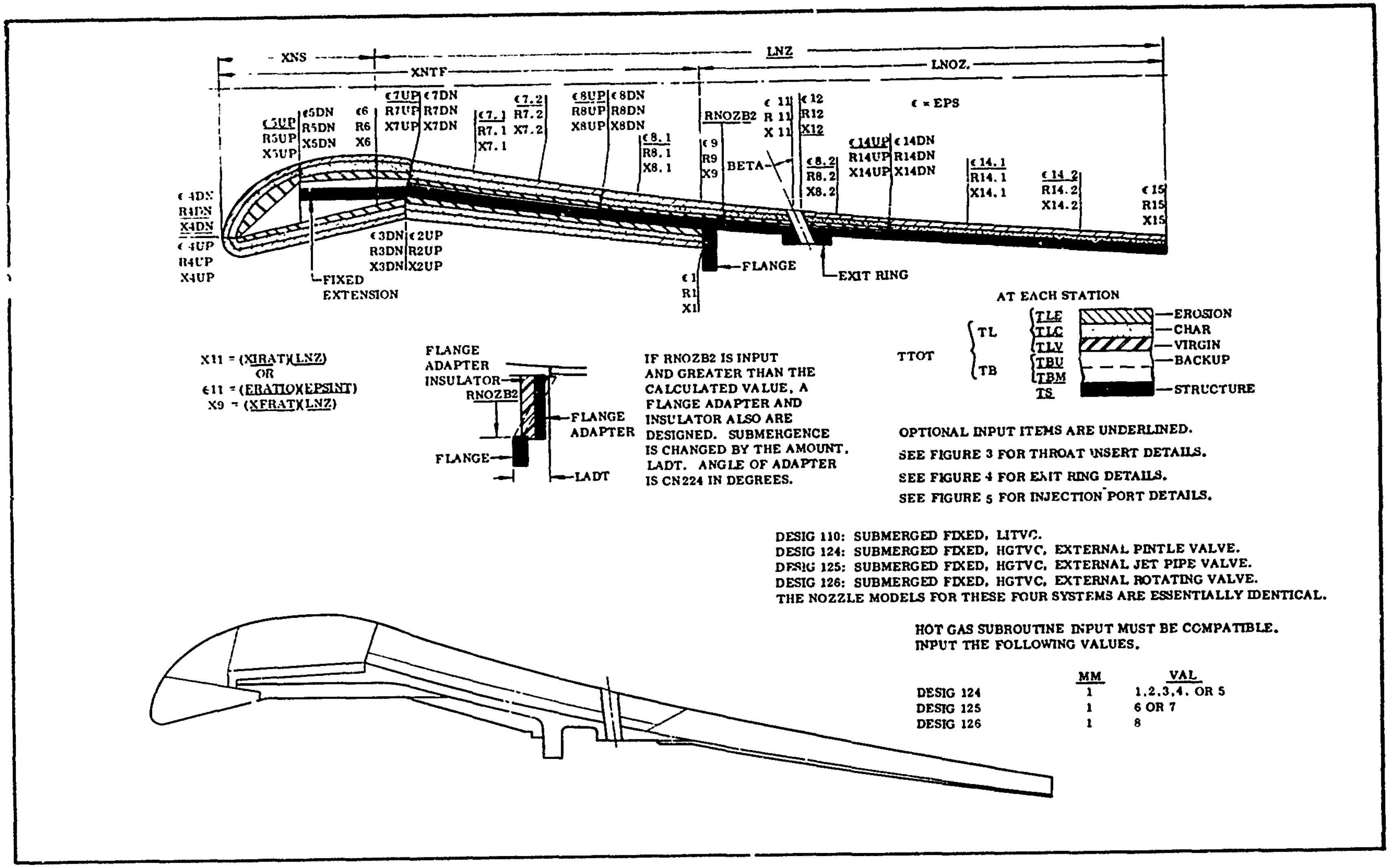


Figure 7. TVC Computer Program Model, Submerged Nozzle

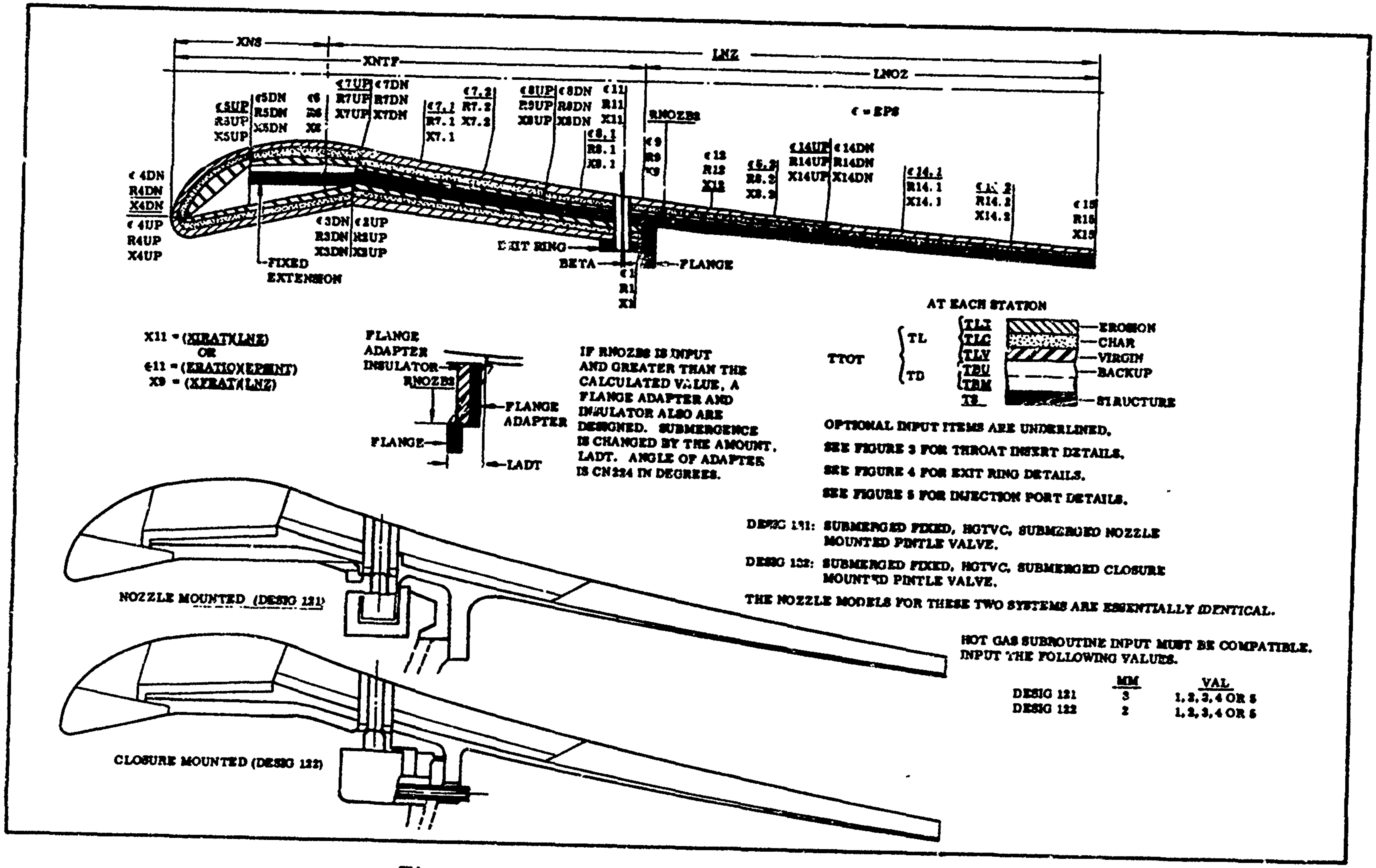


Figure 8. Nozzle DESIG 121 and 122 Diagram

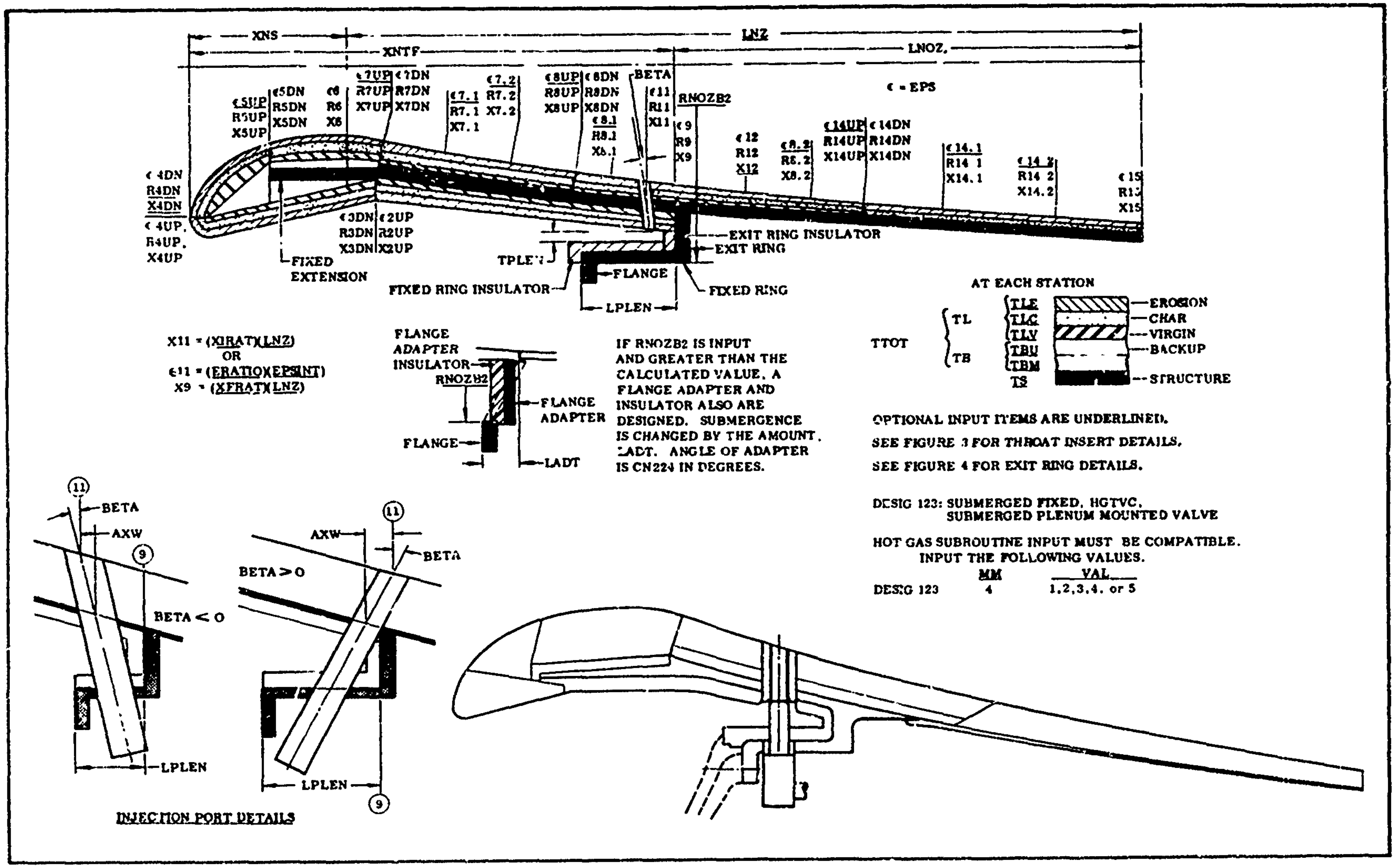


Figure 9. Nozzle DESIG 123 Diagram

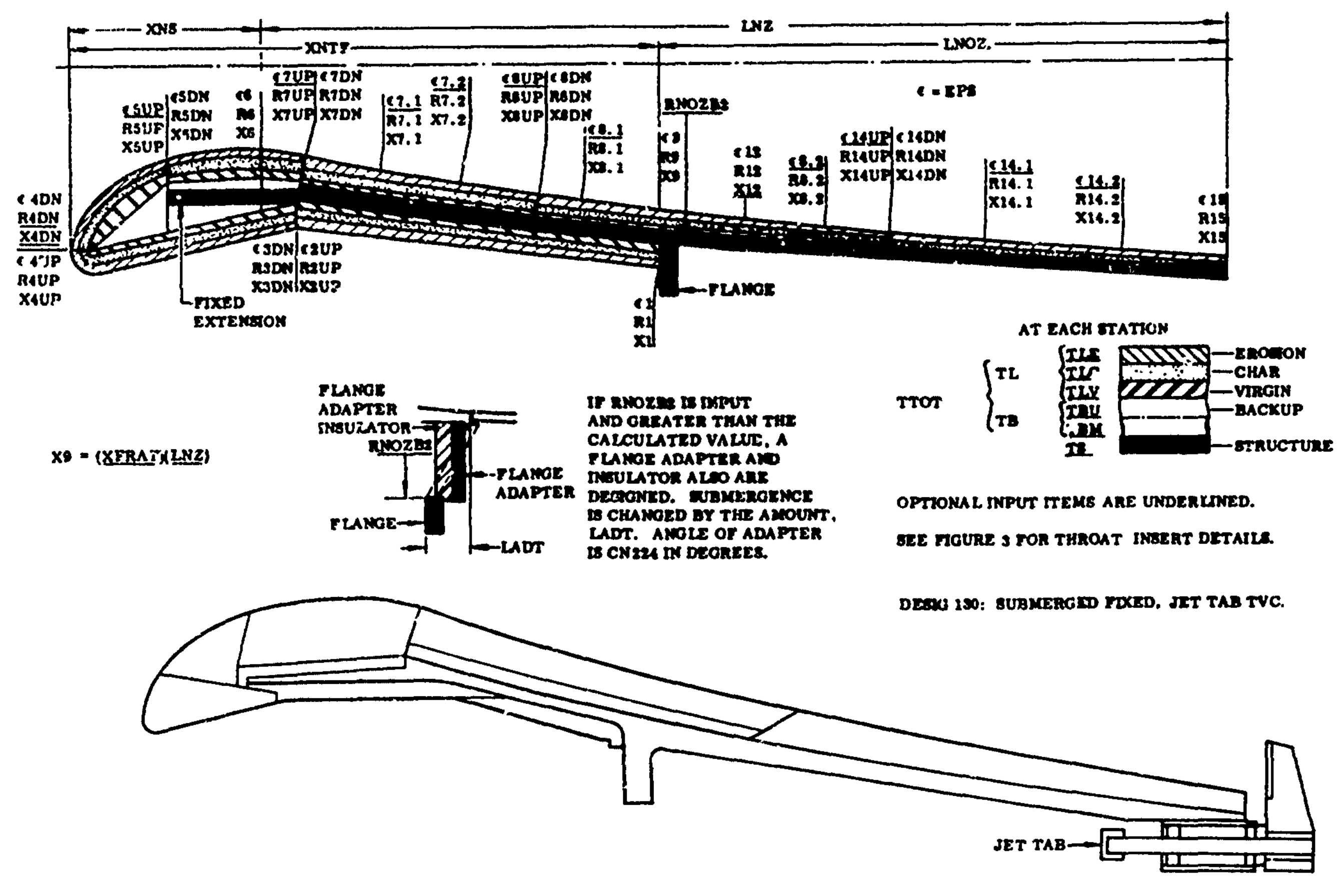


Figure 10. Nozzle DESIG 130 Diagram

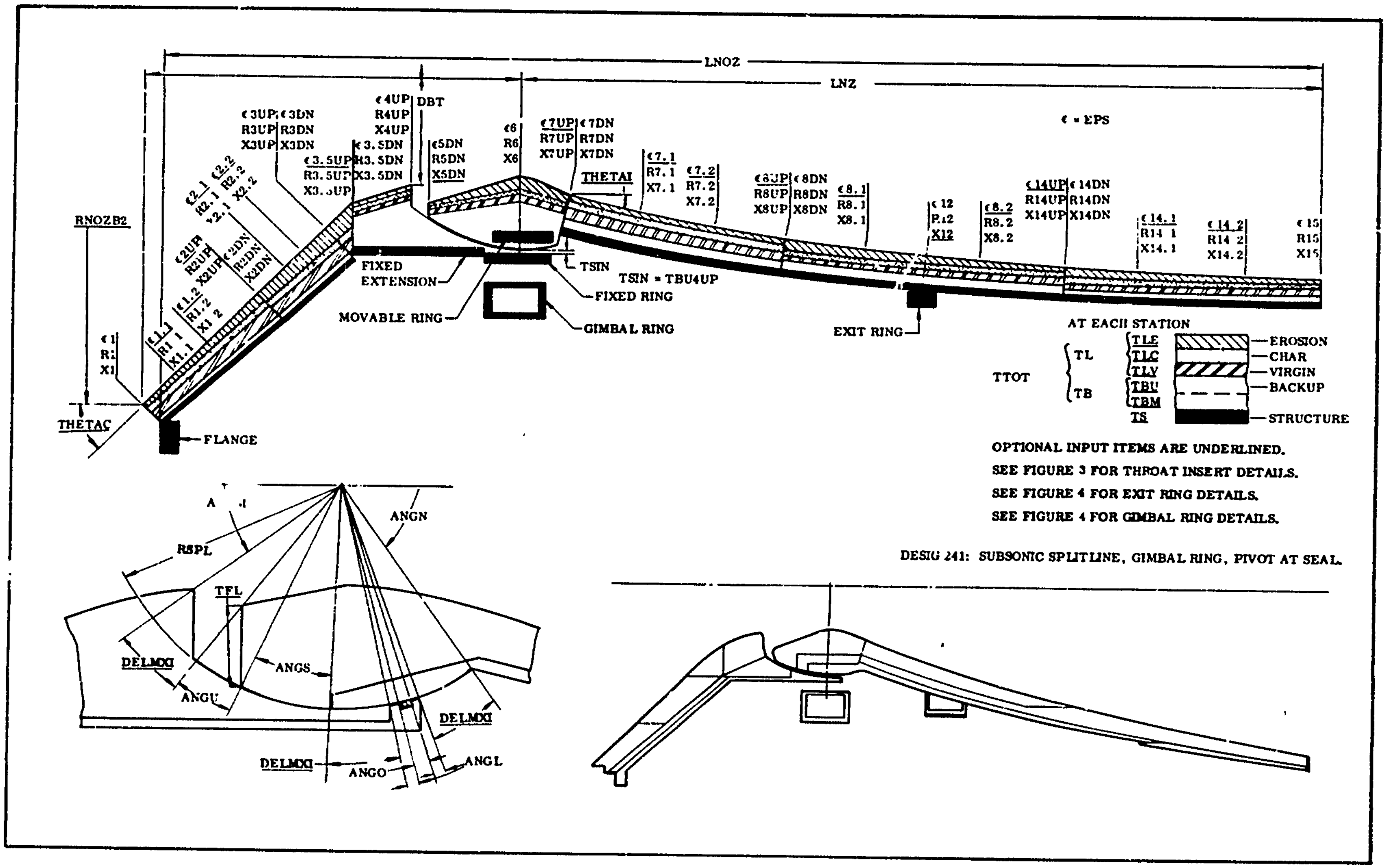


Figure 11. Nozzle DESIG 241 Diagram

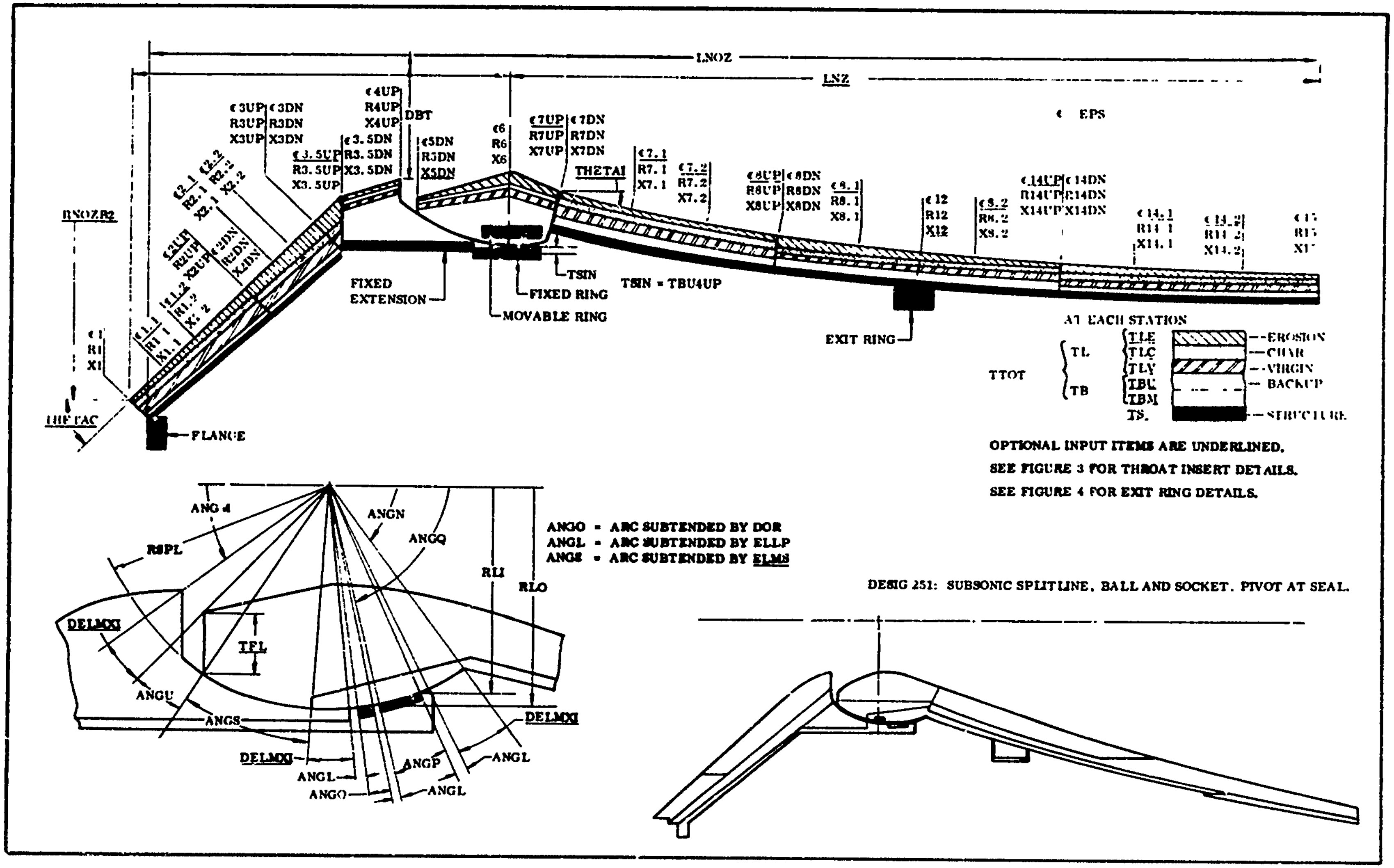


Figure 12. Nozzle DESIG 251 Diagram

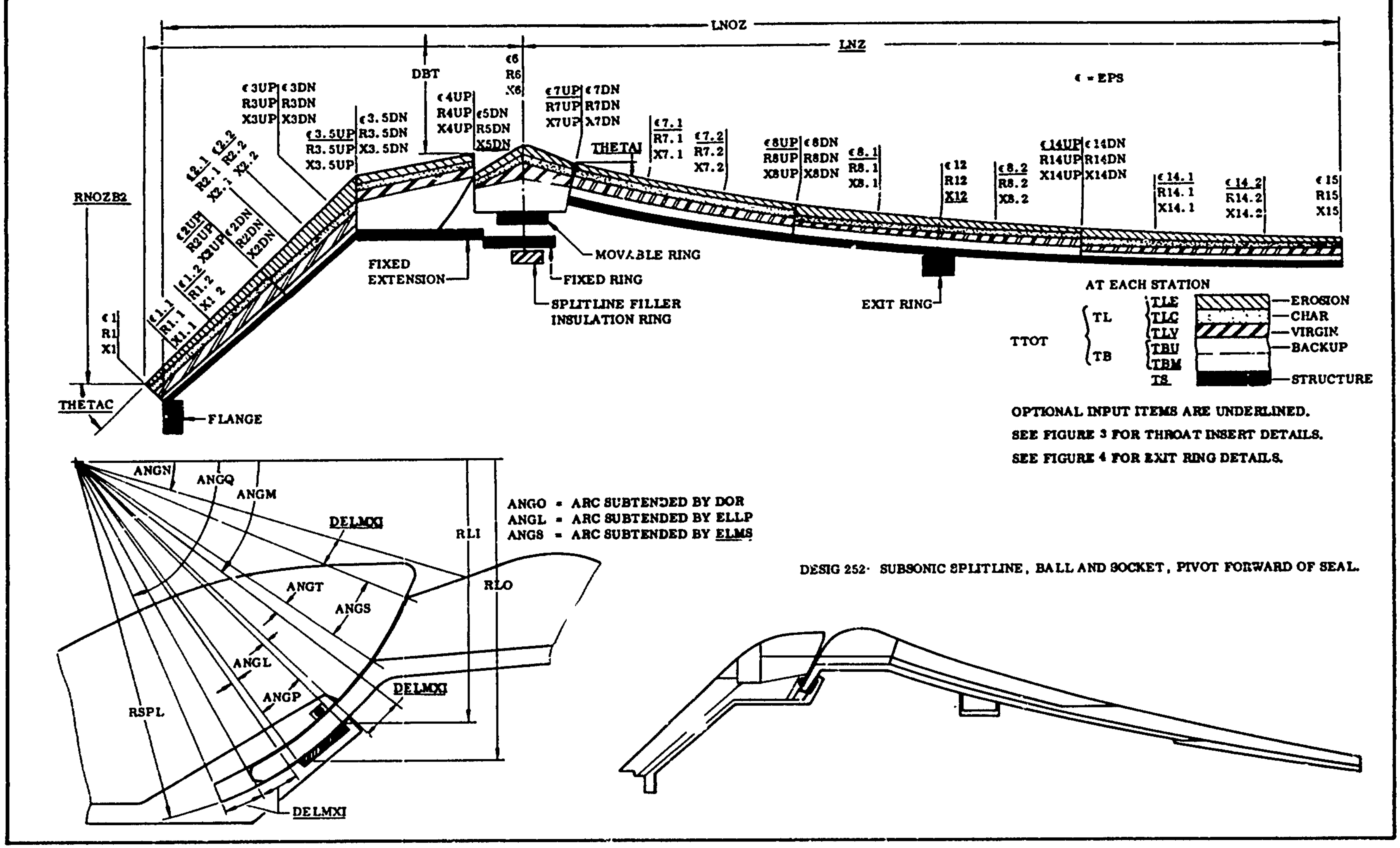


Figure 13. Nozzle DESIG 252 Diagram

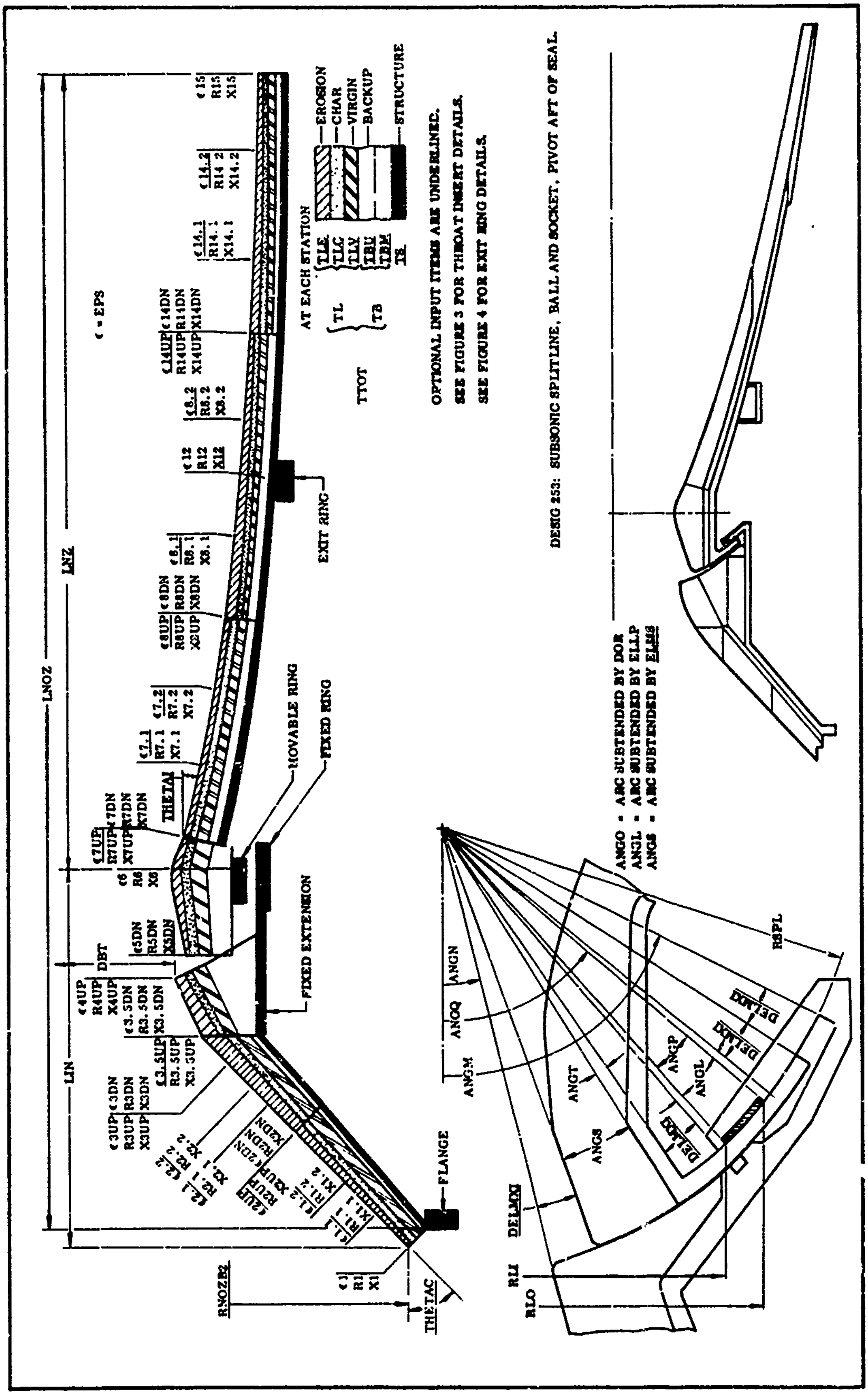


Figure 14. Nozzle DESIG 253 Diagram

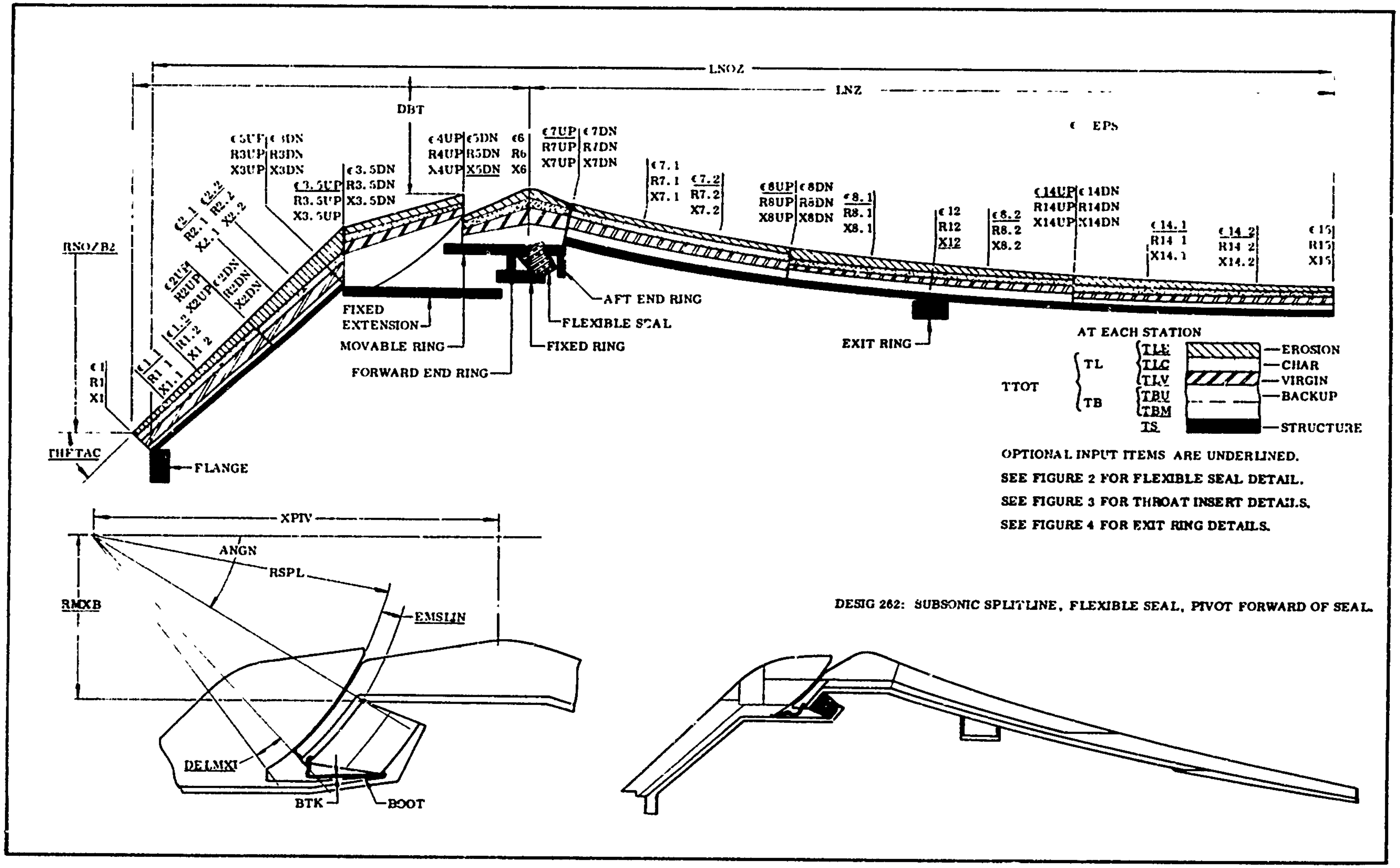


Figure 15. Nozzle DESIG 262 Diagram

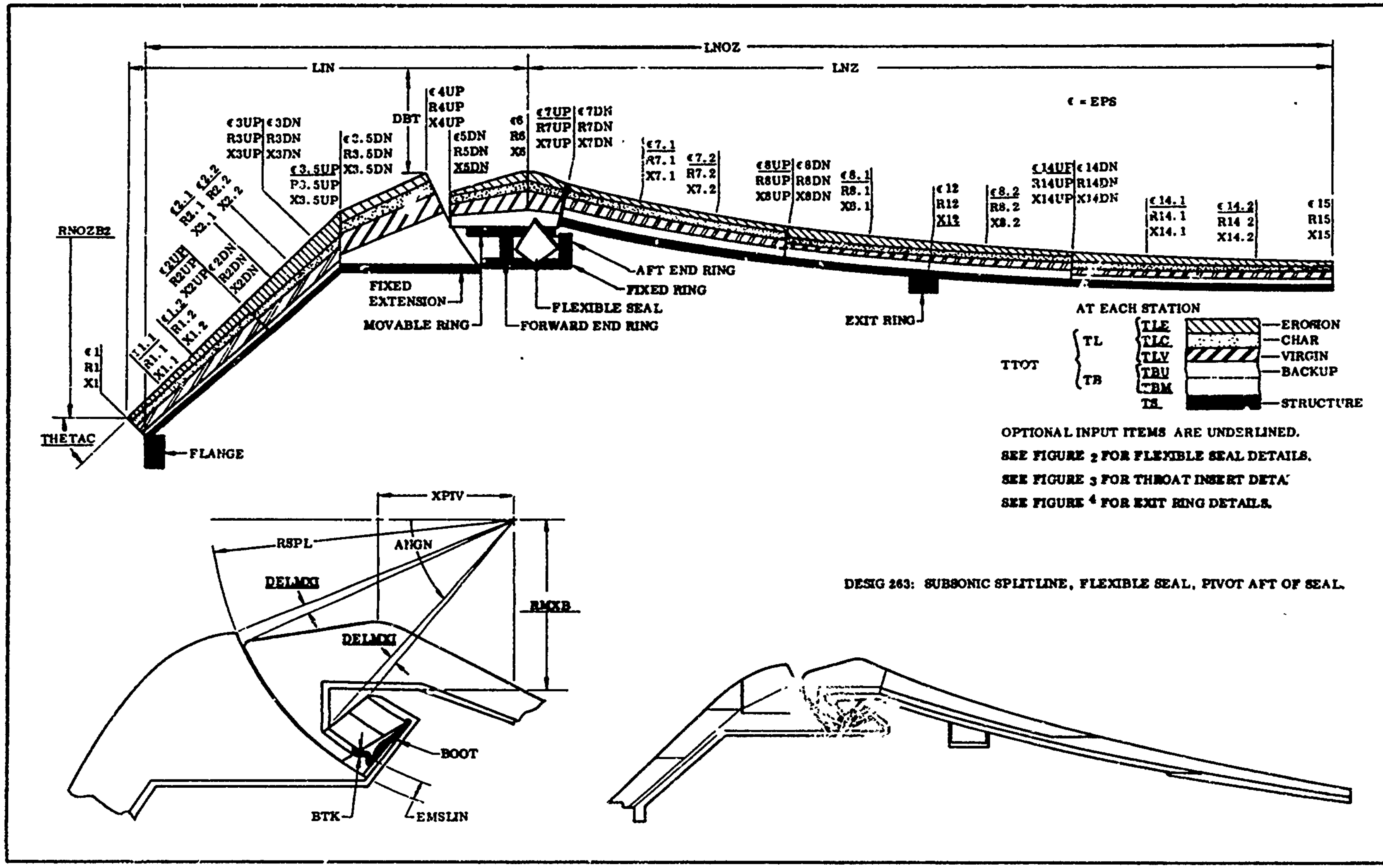


Figure 16. Nozzle DESIG 263 Diagram

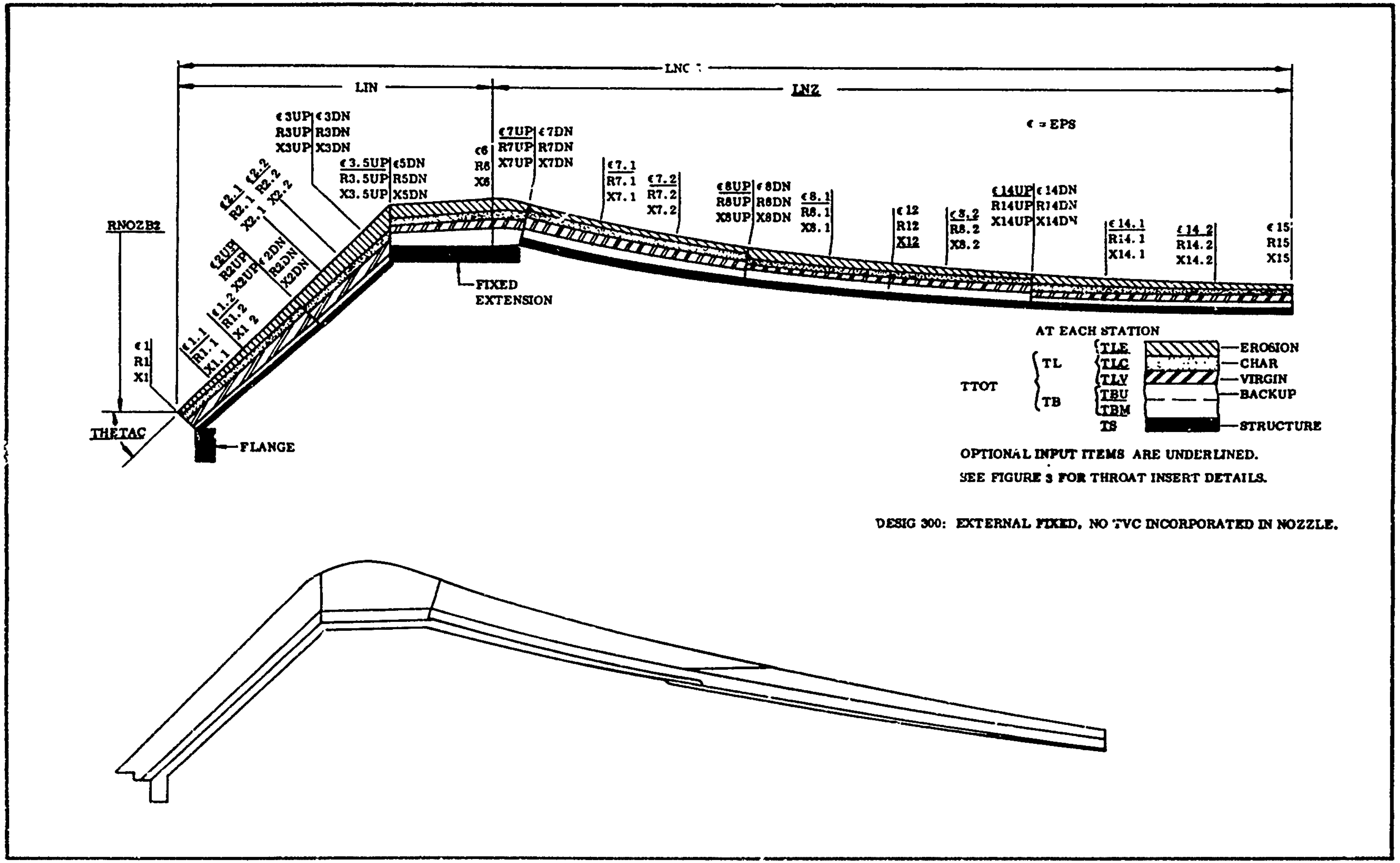


Figure 17. Nozzle DESIG 300 Diagram

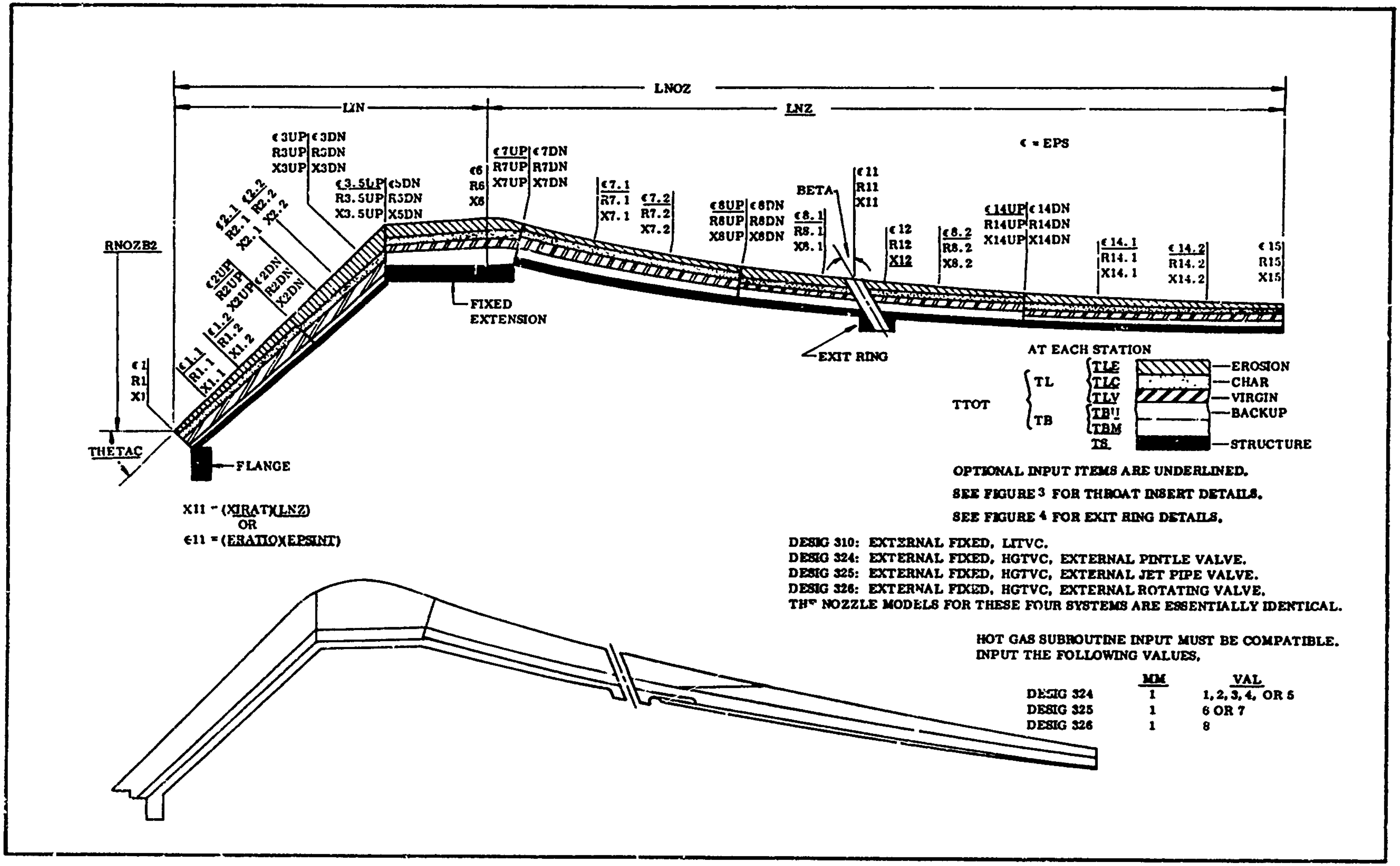


Figure 18. Nozzle DESIG 310, 324, 325, and 326 Diagram

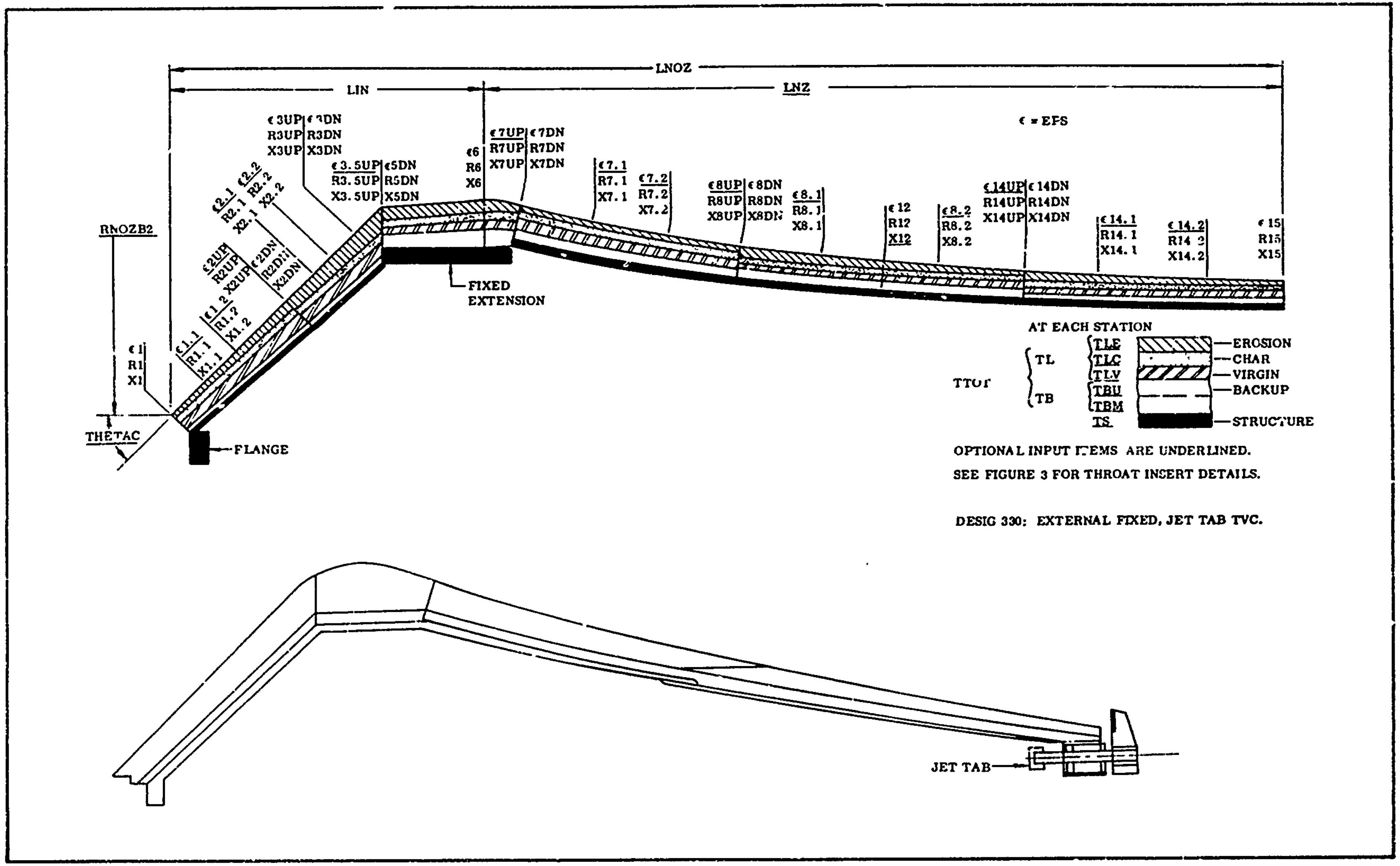


Figure 19. Nozzle DESIG 330 Diagram

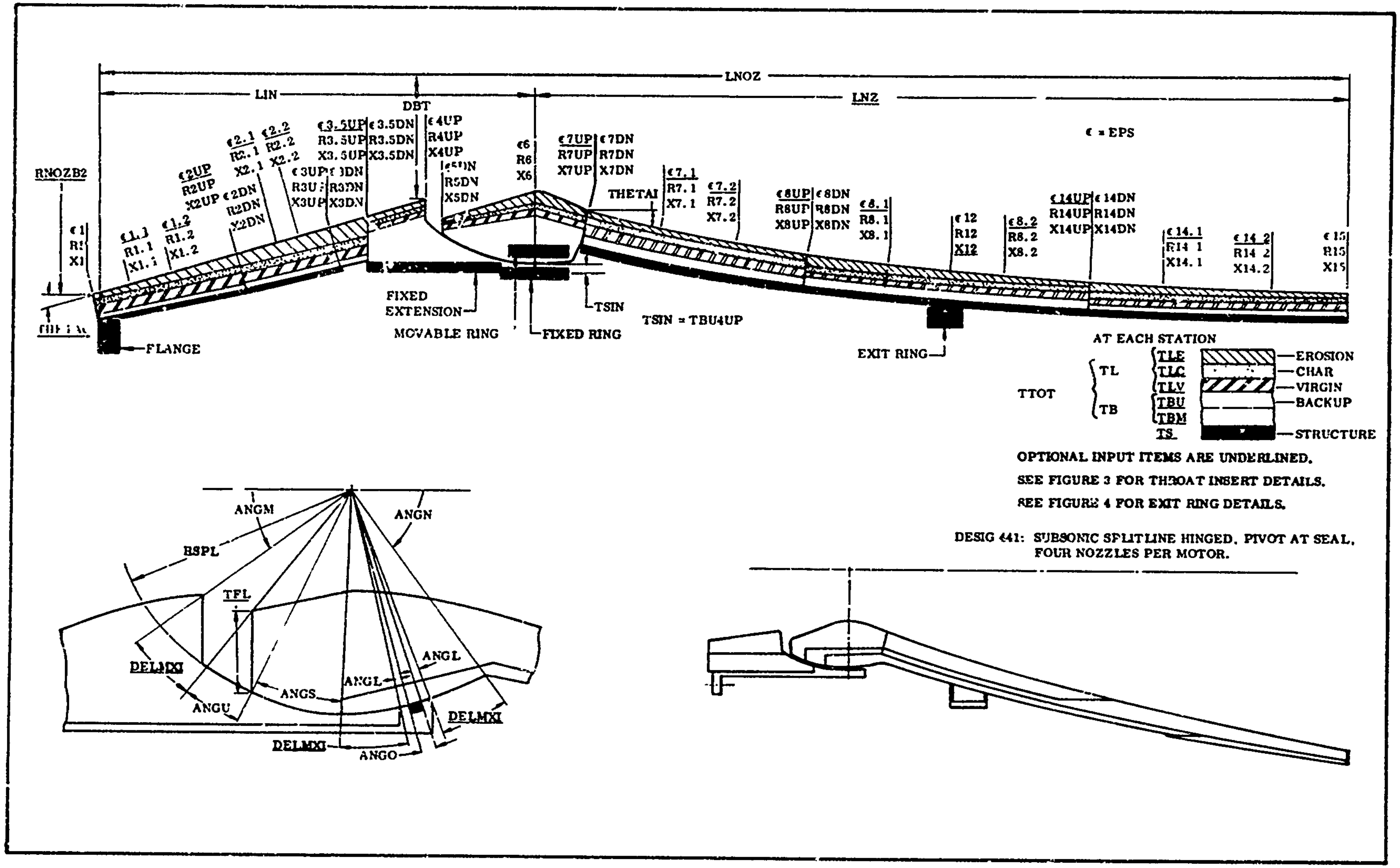


Figure 20. Nozzle DESIG 441 Diagram

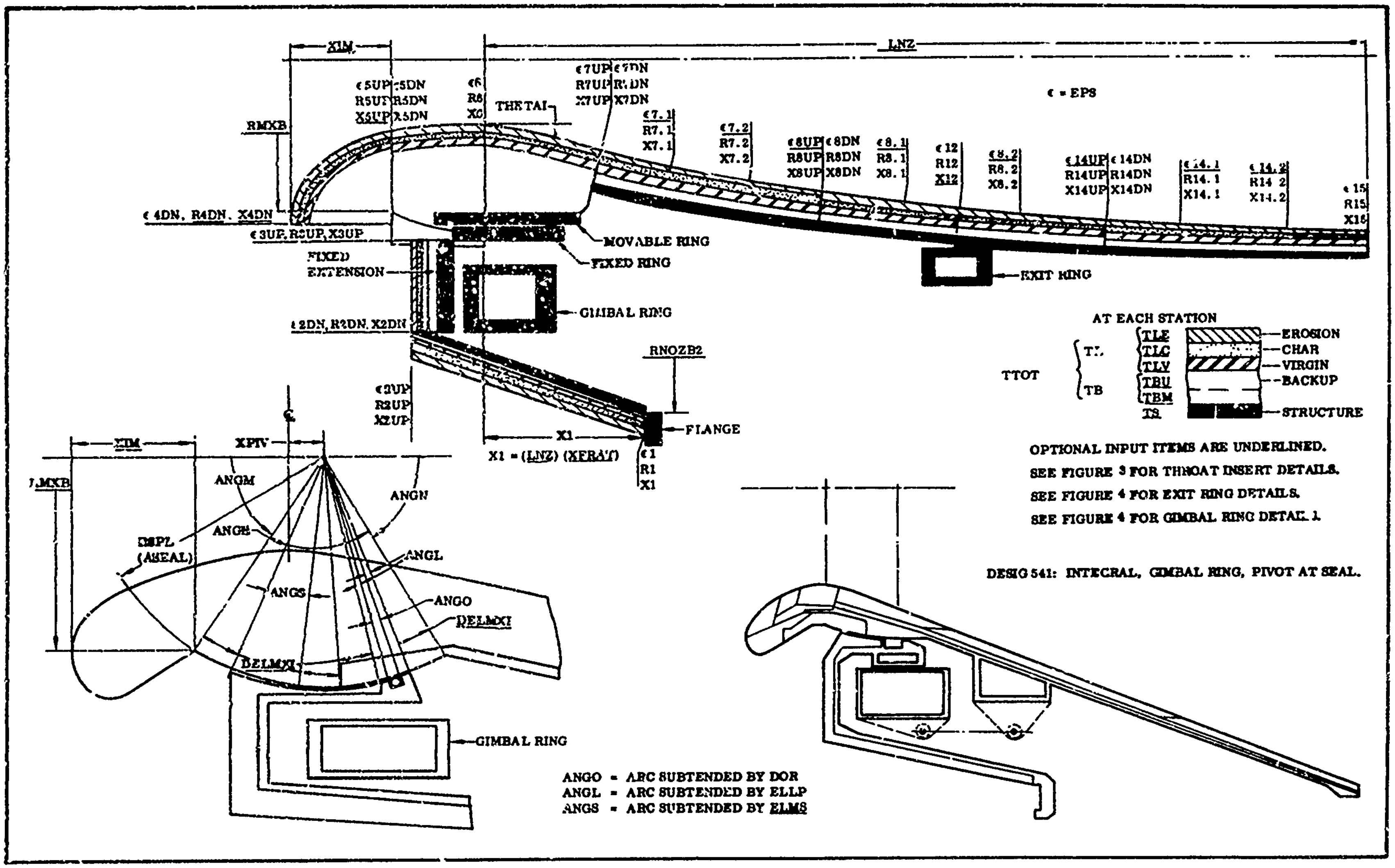


Figure 21. Nozzle DESIG 541 Diagram

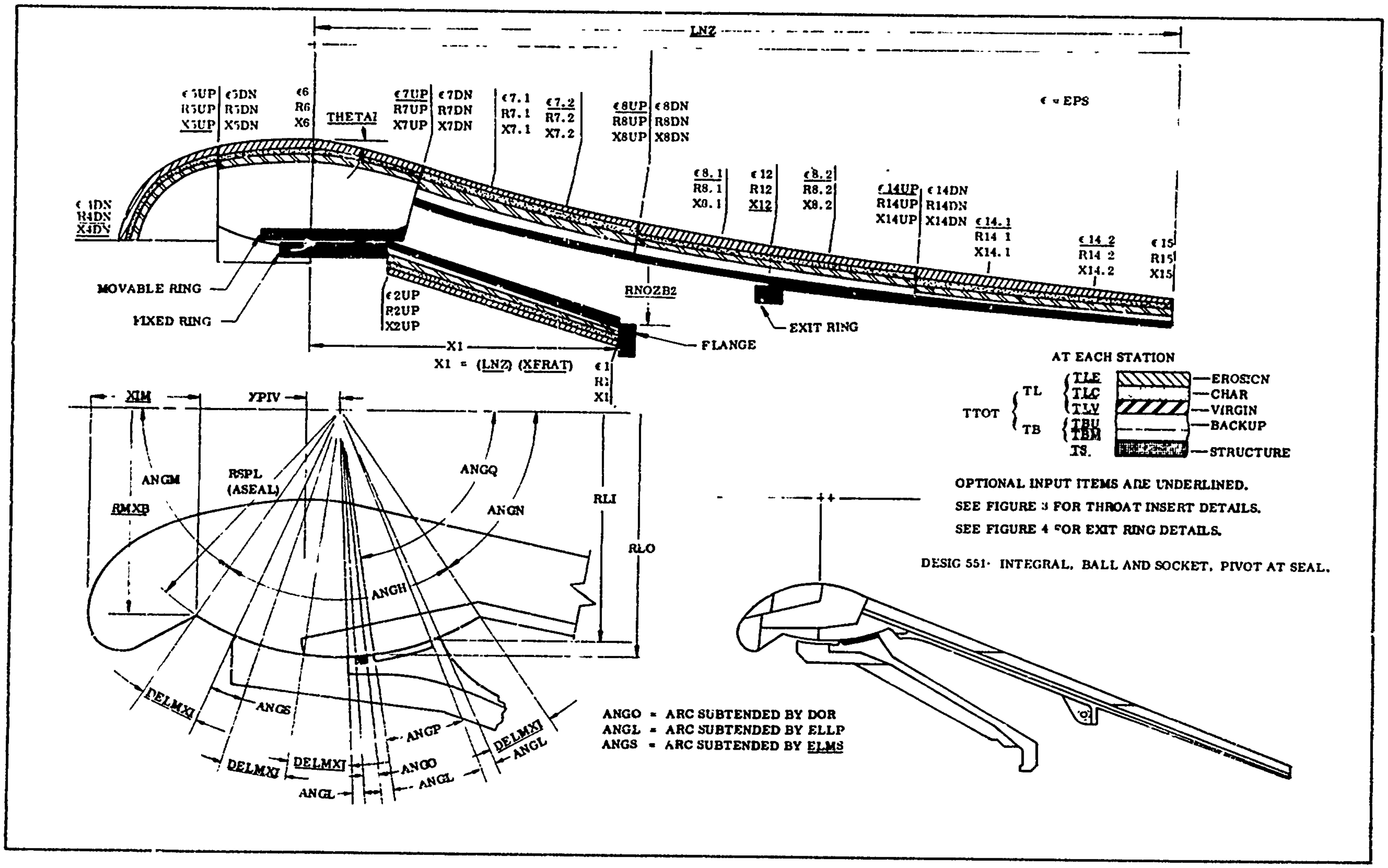


Figure 22. Nozzle DESIG 551 Diagram

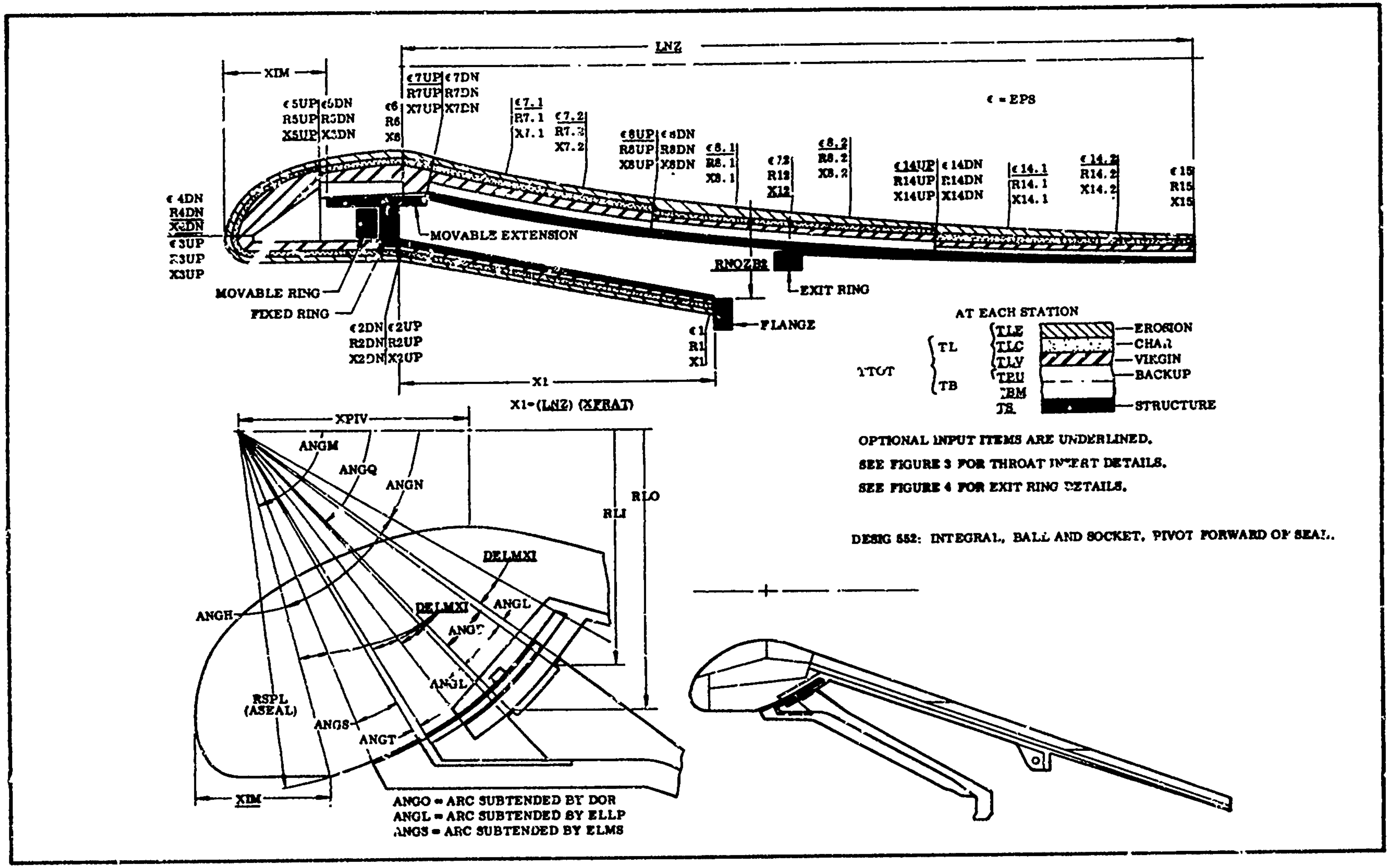


Figure 23. Nozzle DESIG 552 Diagram

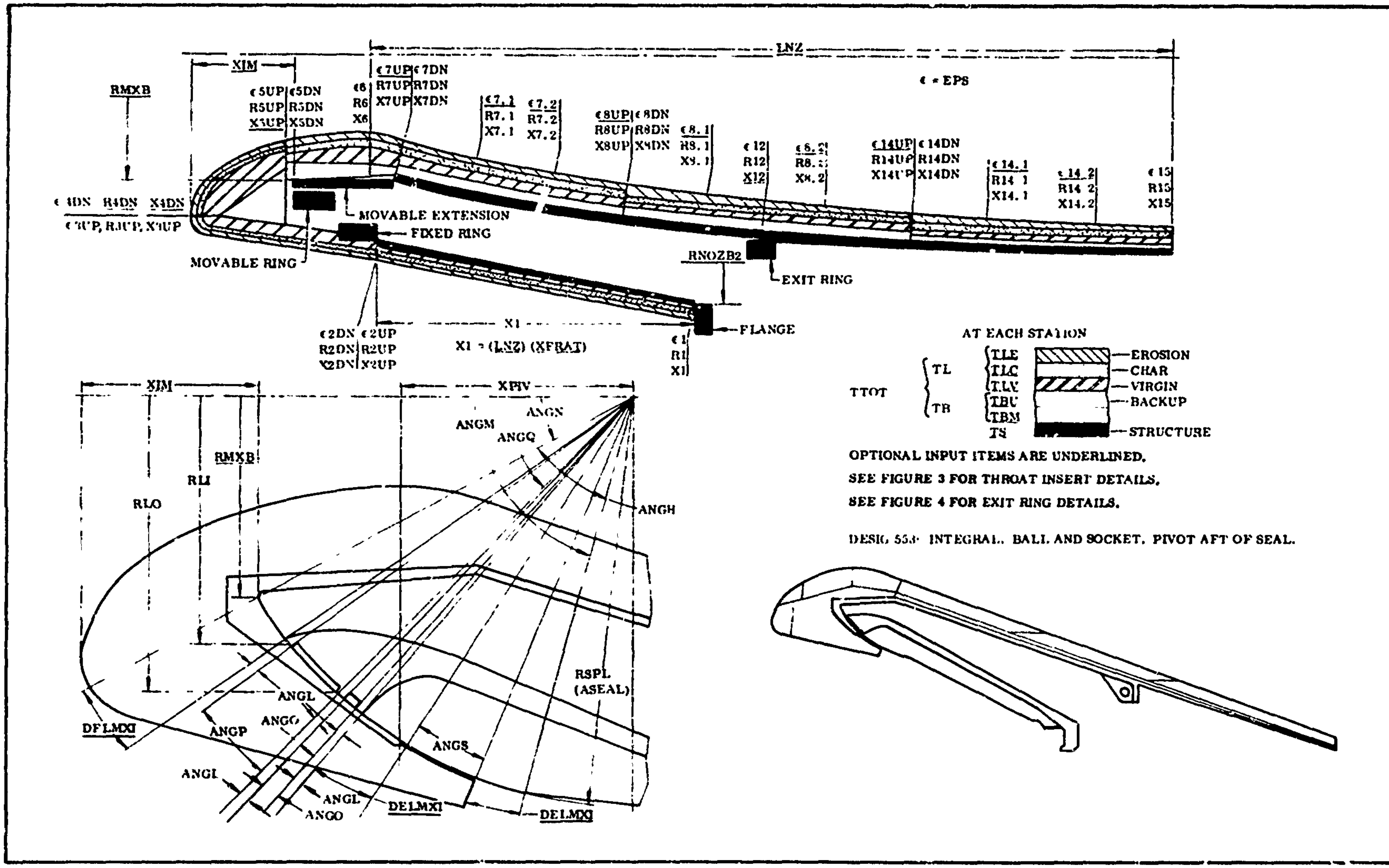


Figure 24. Nozzle DESIG 553 Diagram

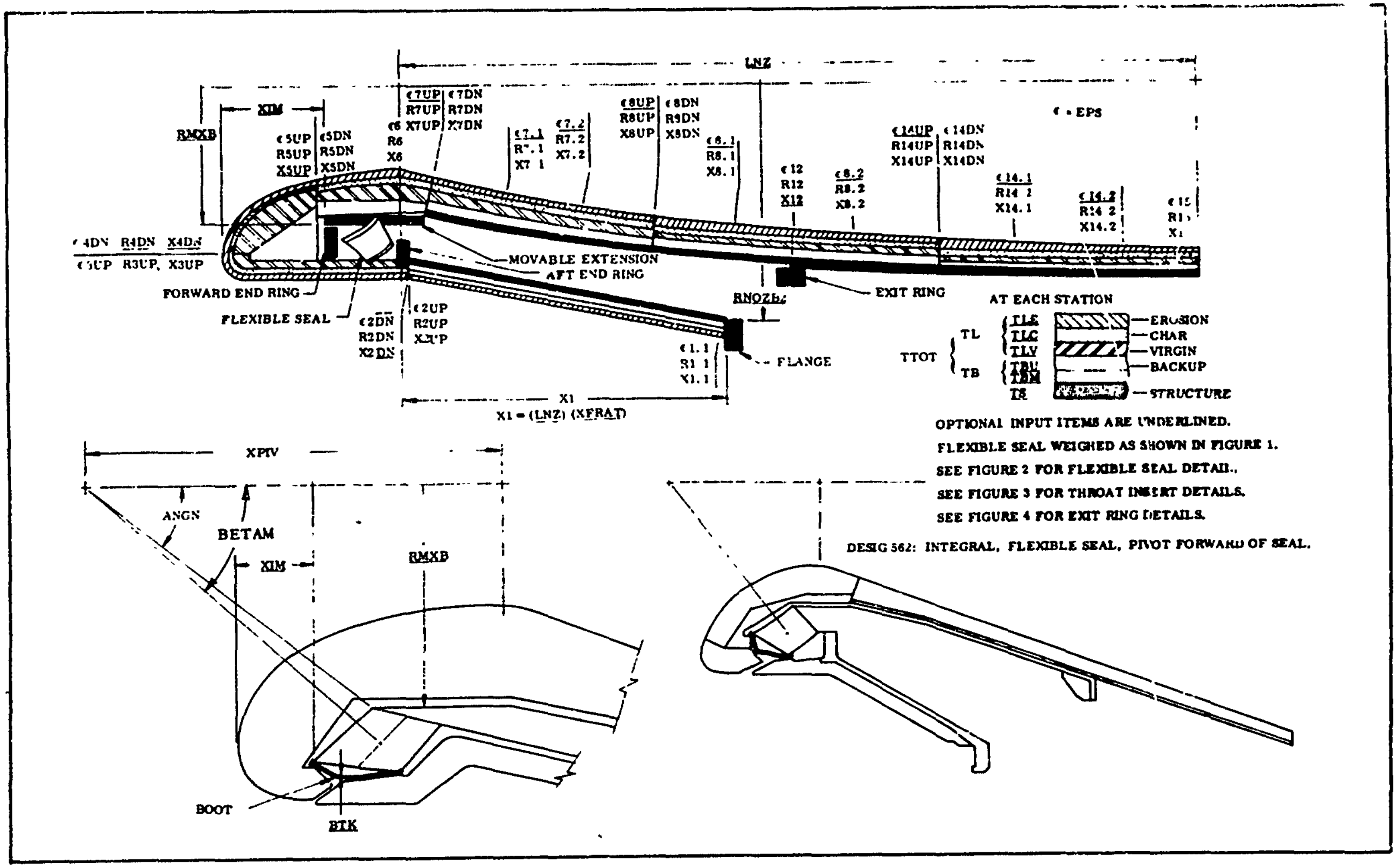


Figure 25. Nozzle DESIG 562 Diagram

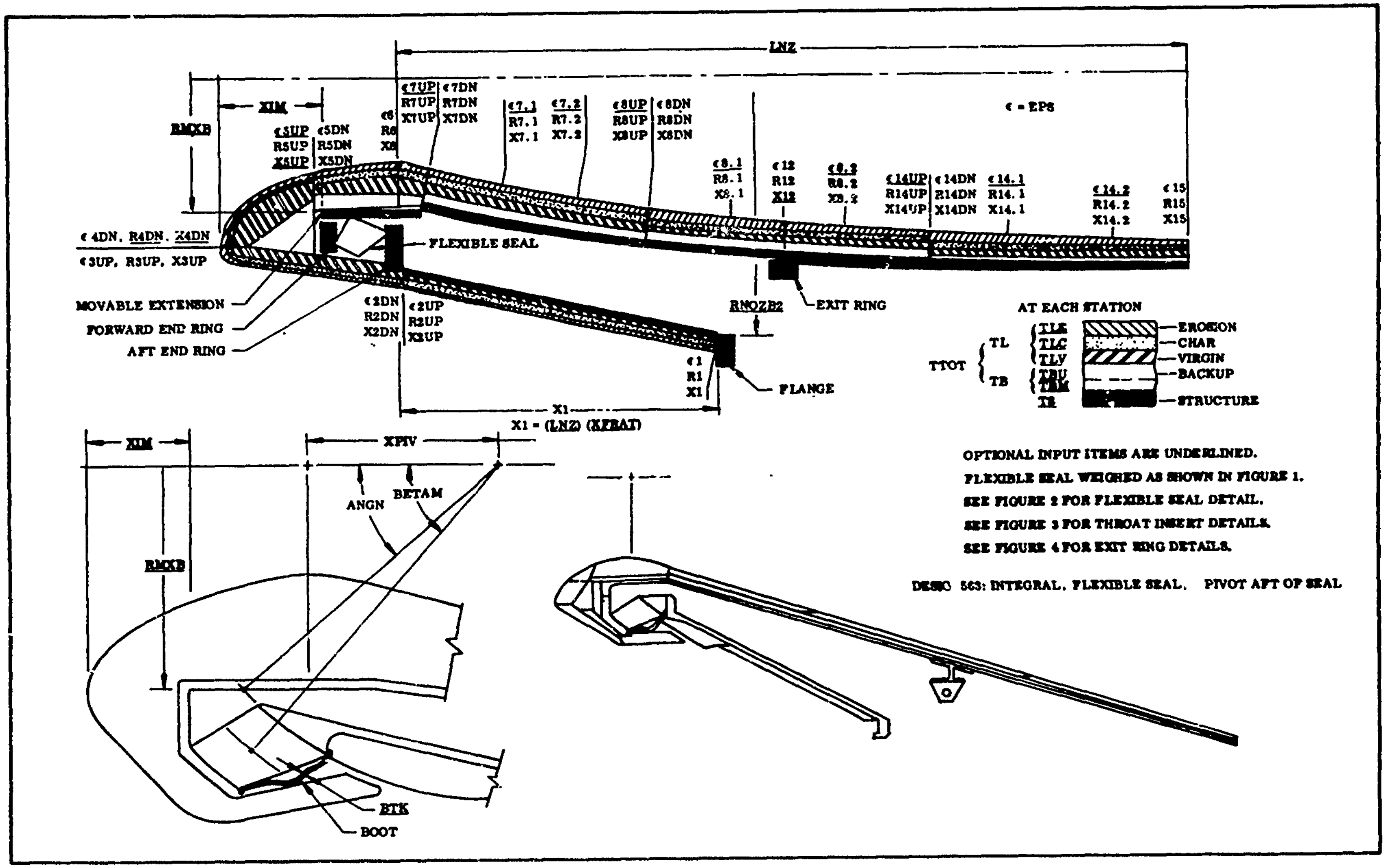


Figure 26. Nozzle DESIG 563 Diagram

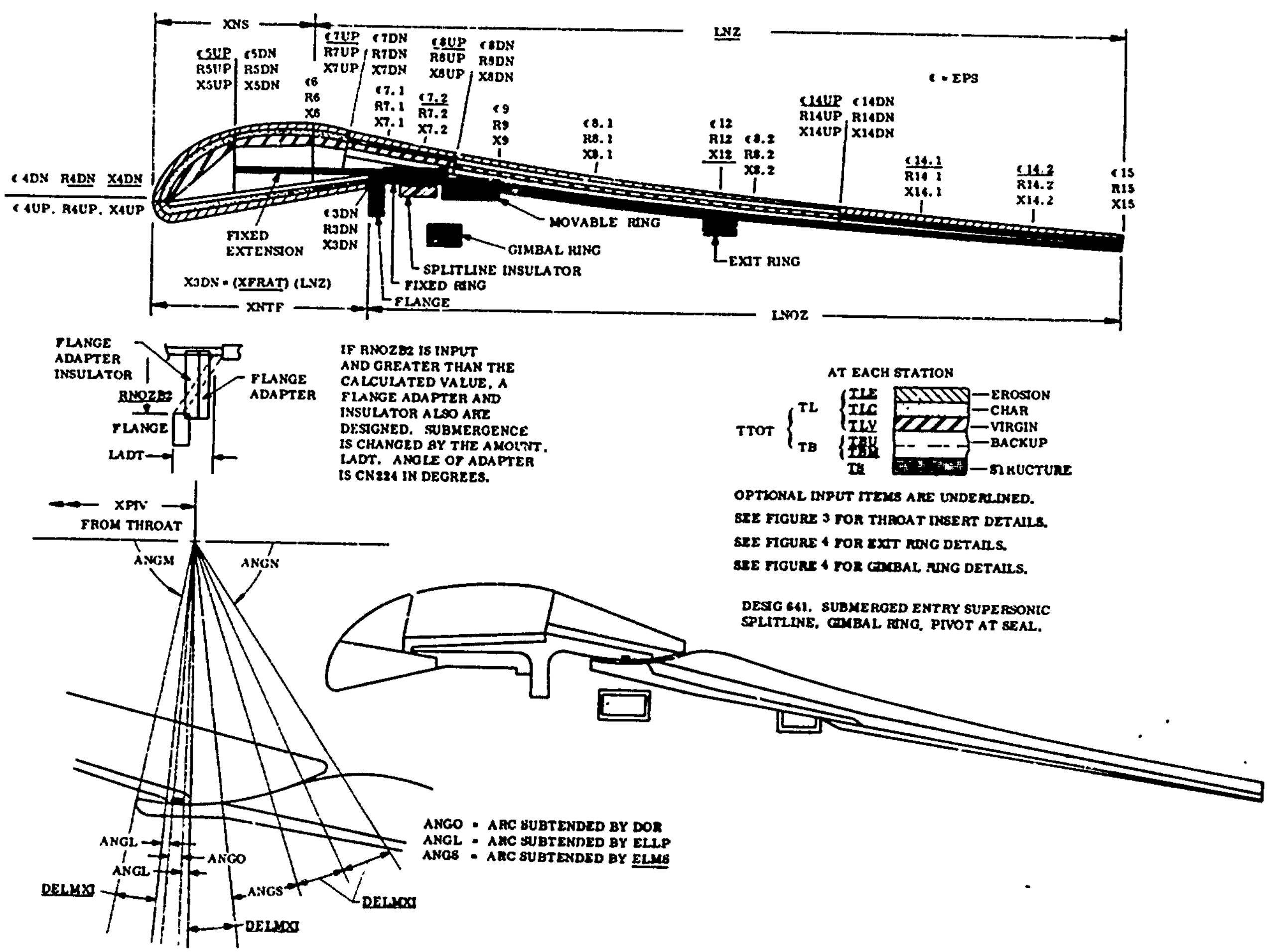


Figure 27. Nozzle DESIG 641 Diagram

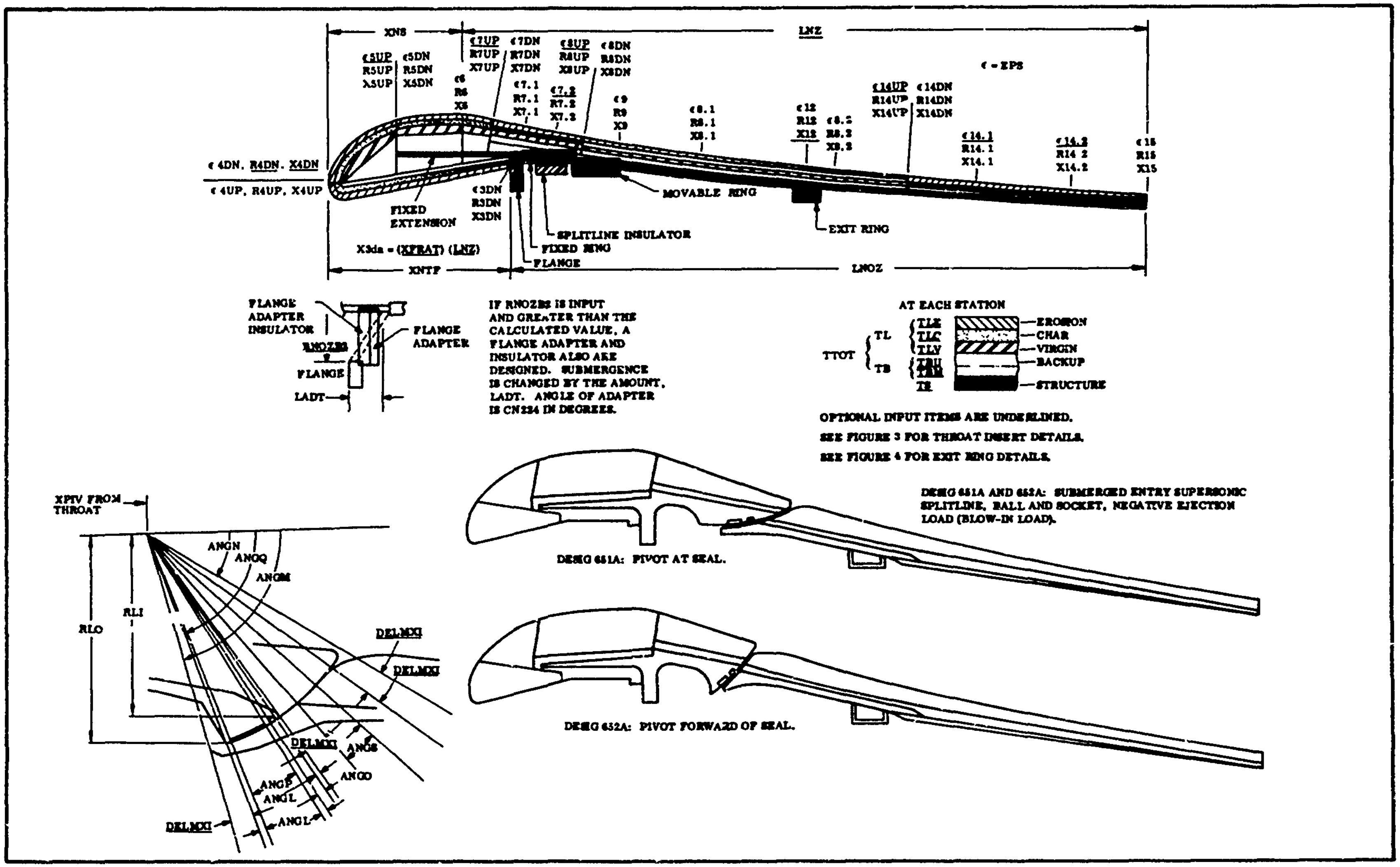


Figure 28. Nozzle DESIG 651A and 652A Diagram

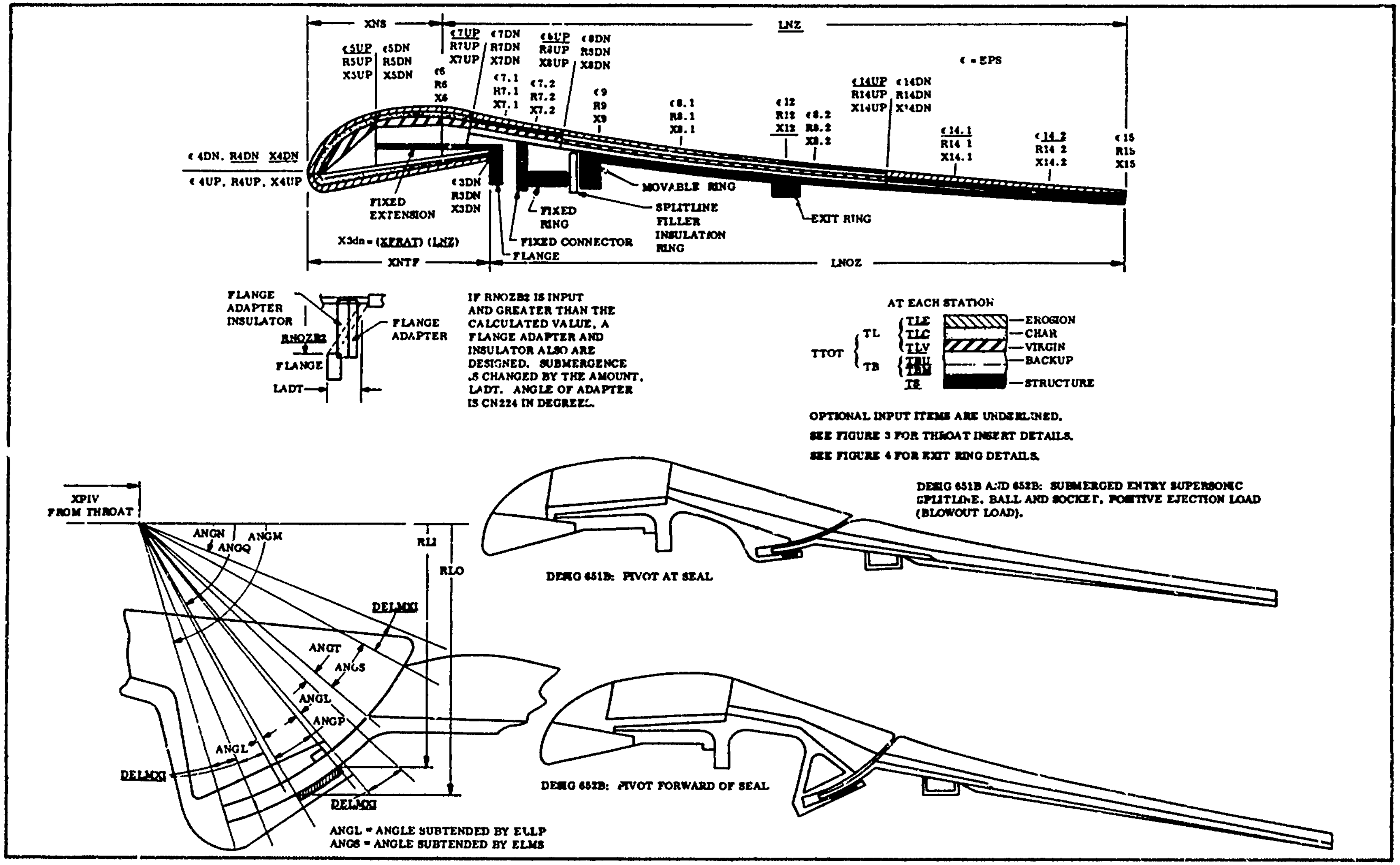


Figure 29. Nozzle DESIG 651B and 652B Diagram

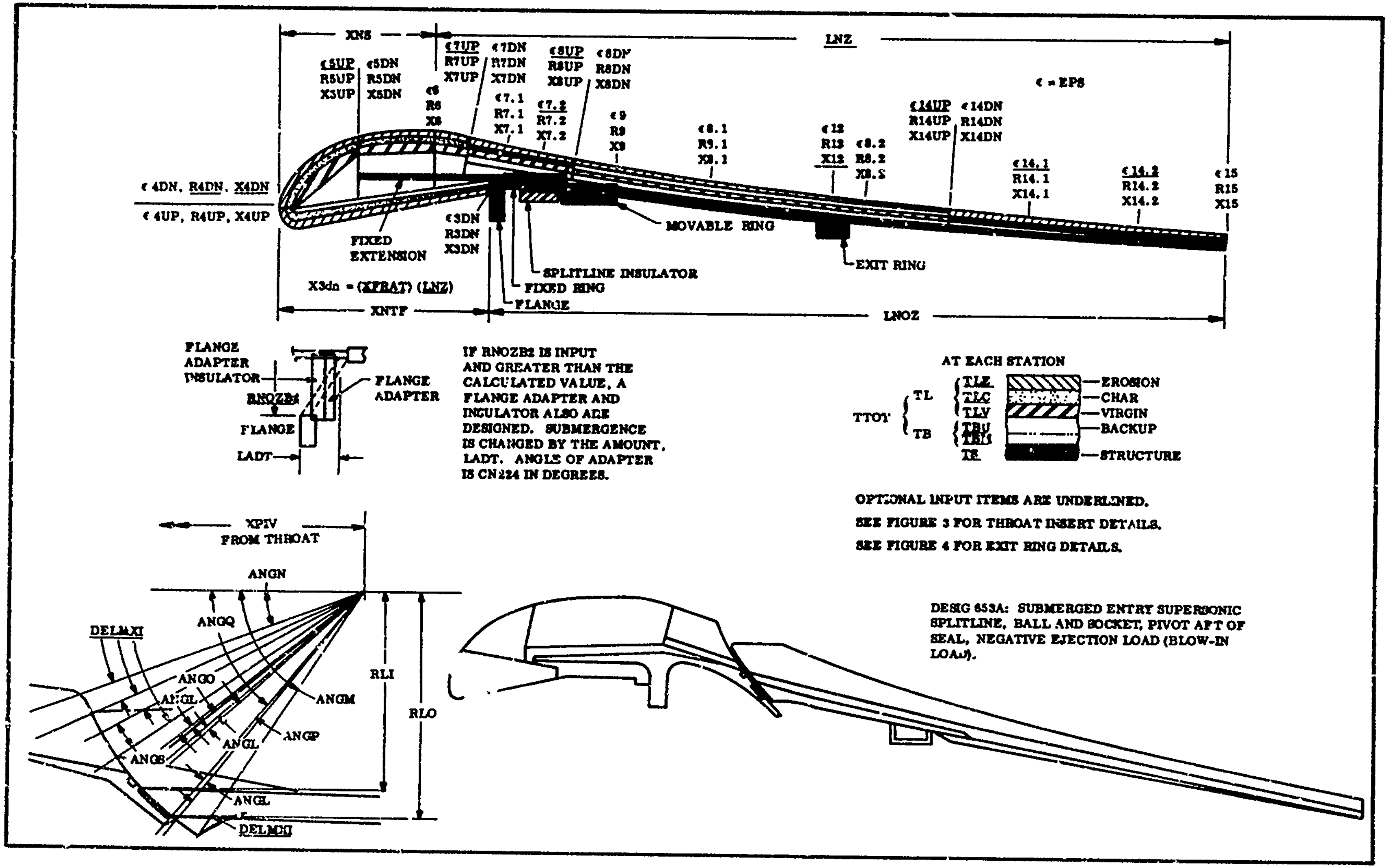


Figure 30. Nozzle DESIG 653A Diagram

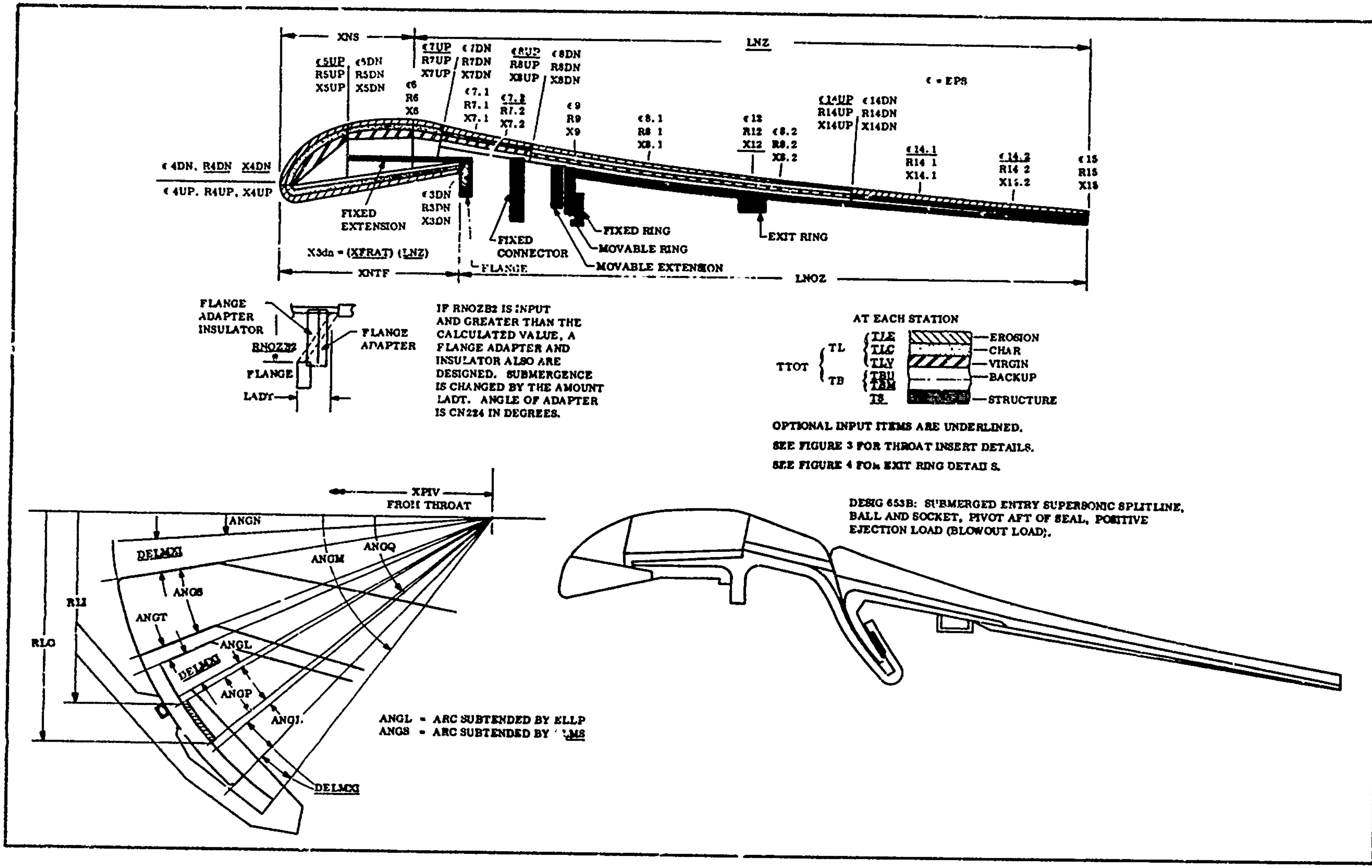


Figure 31. Nozzle DESIG 653B Diagram

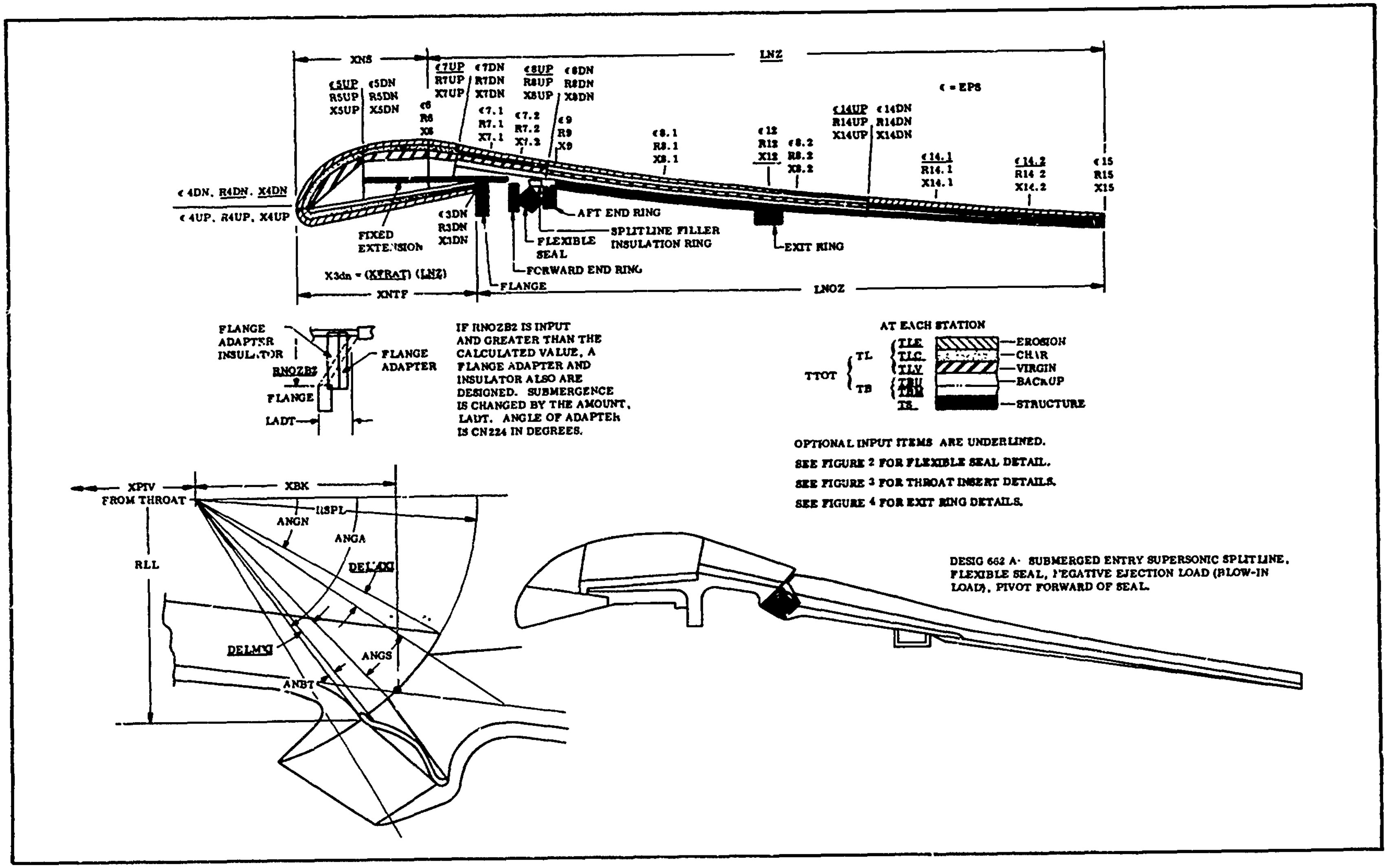


Figure 32. Nozzle DESIG 662A Diagram

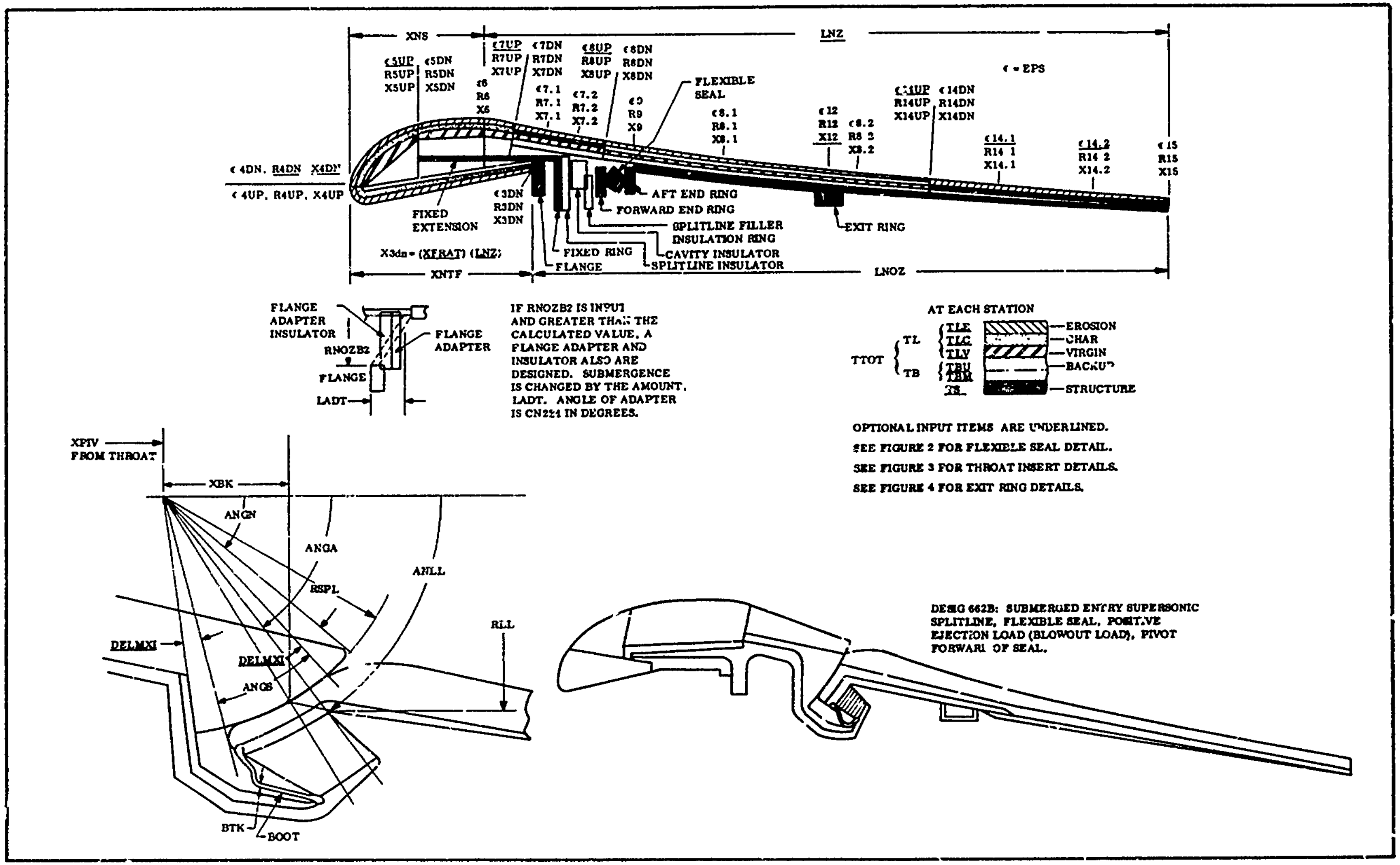


Figure 33. Nozzle DESIG 662B Diagram

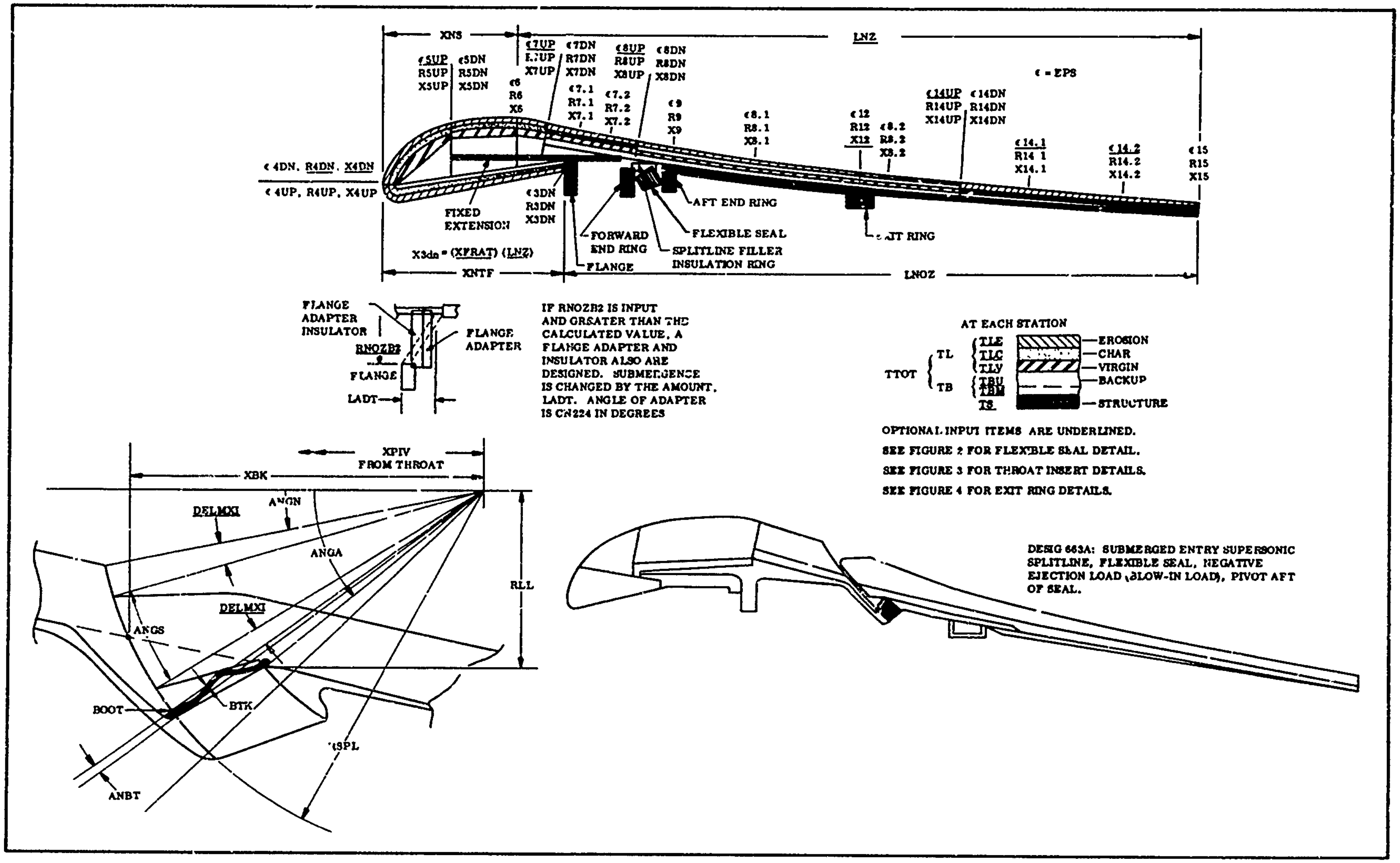


Figure 34. Nozzle DESIG 663A Diagram

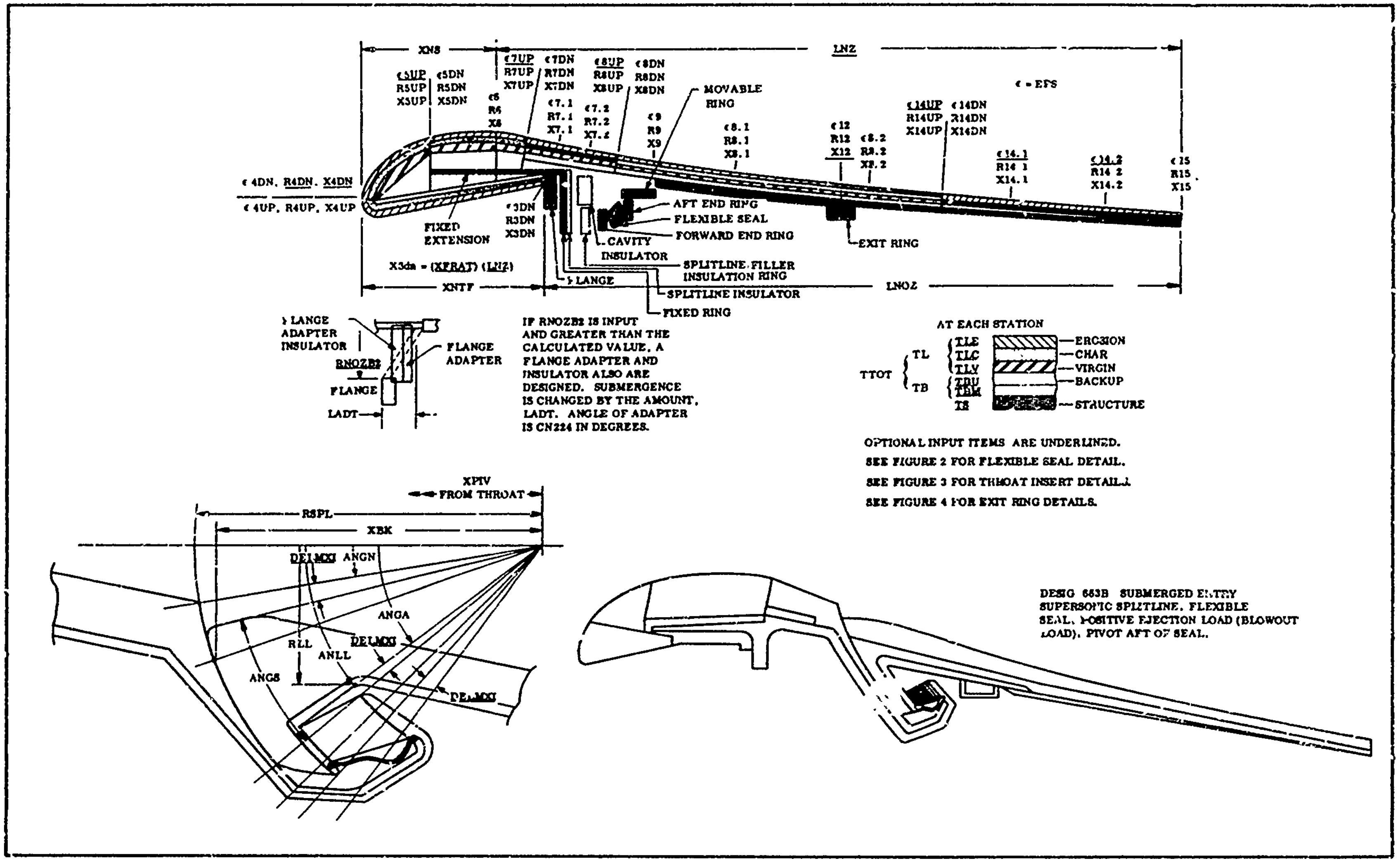


Figure 35. Nozzle DESIG 663B Diagram

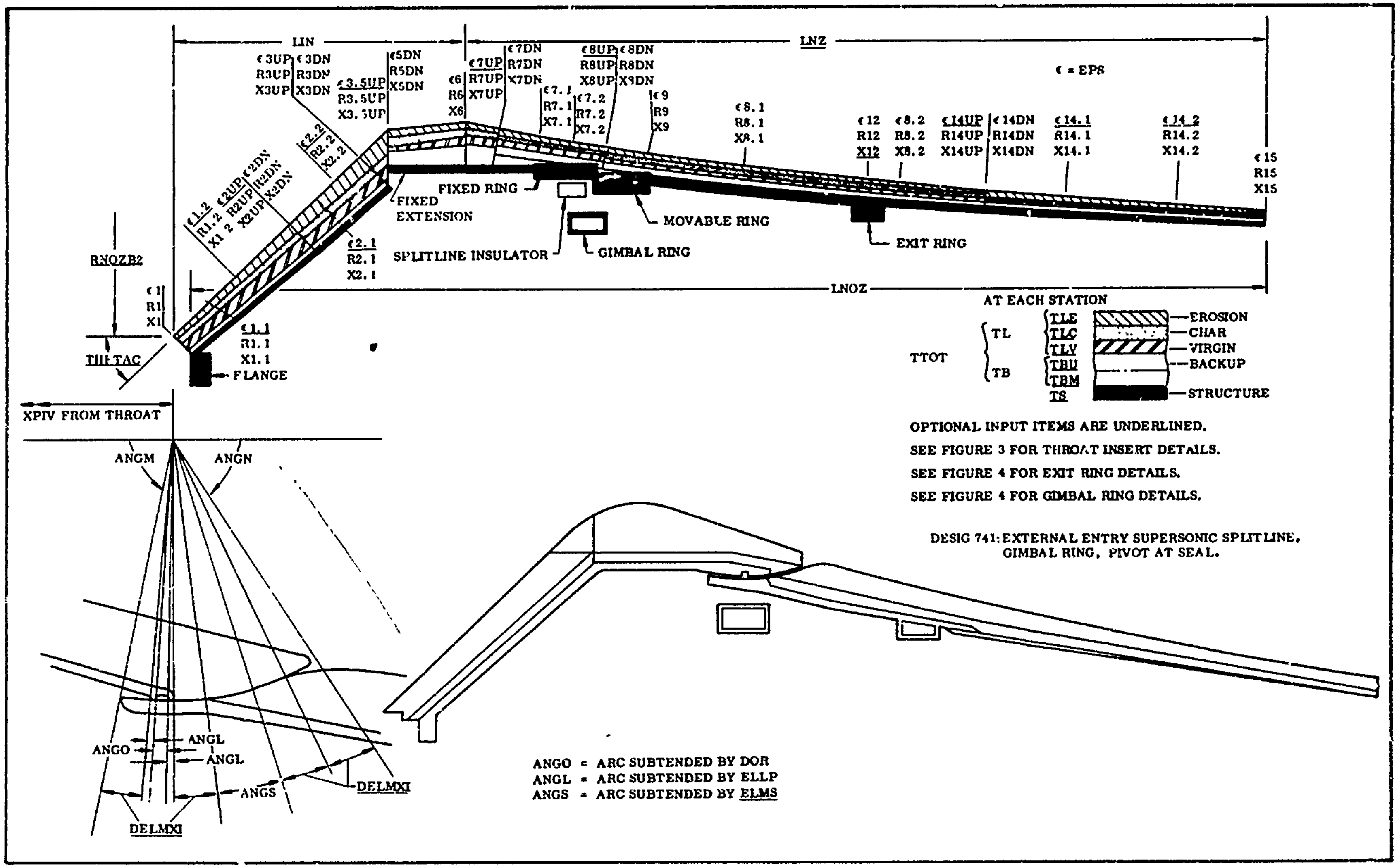


Figure 36. Nozzle DESIG 741 Diagram

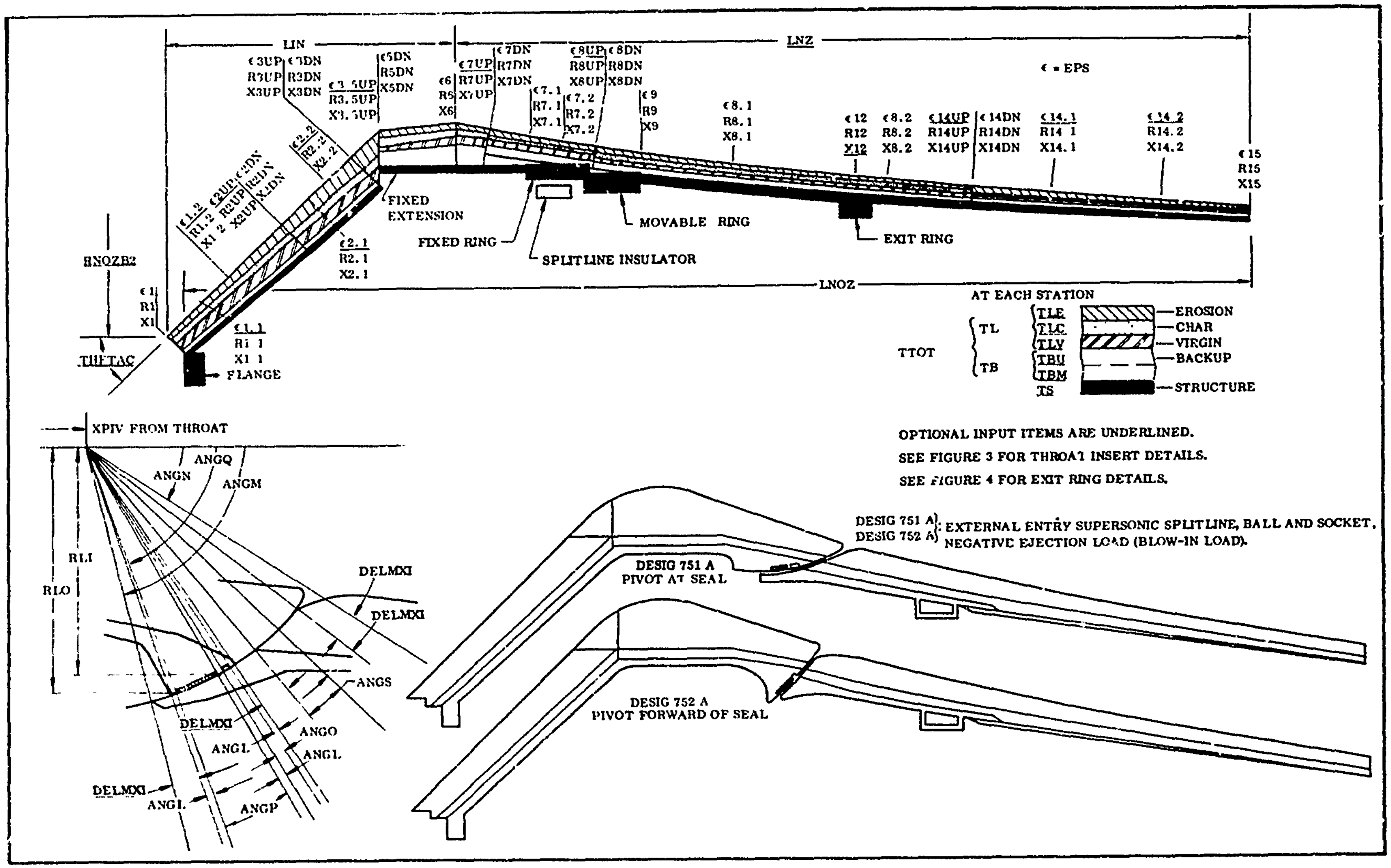


Figure 37. Nozzle DESIG 751A and 752A Diagram

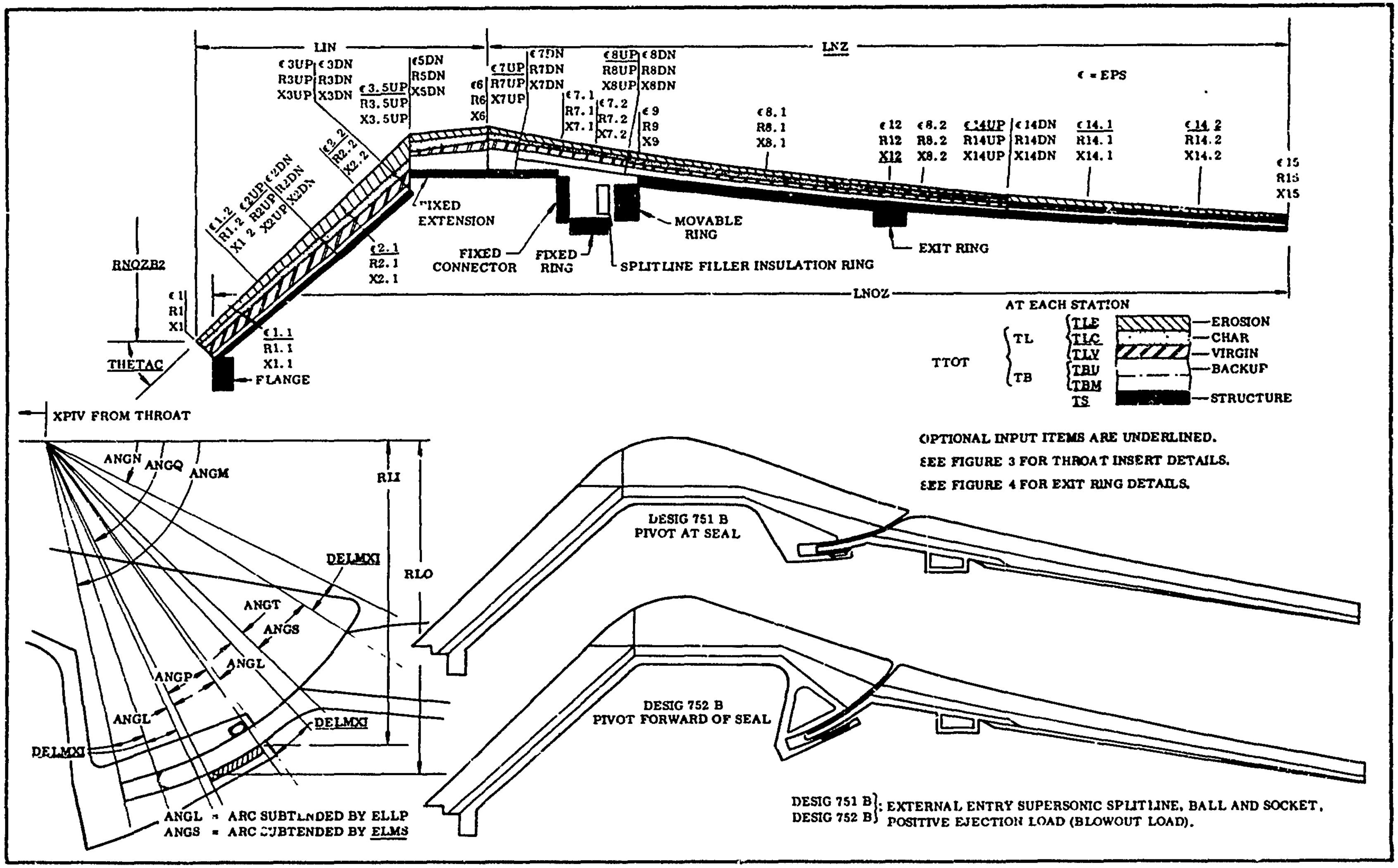


Figure 38. Nozzle DESIG 751B and 752B Diagram

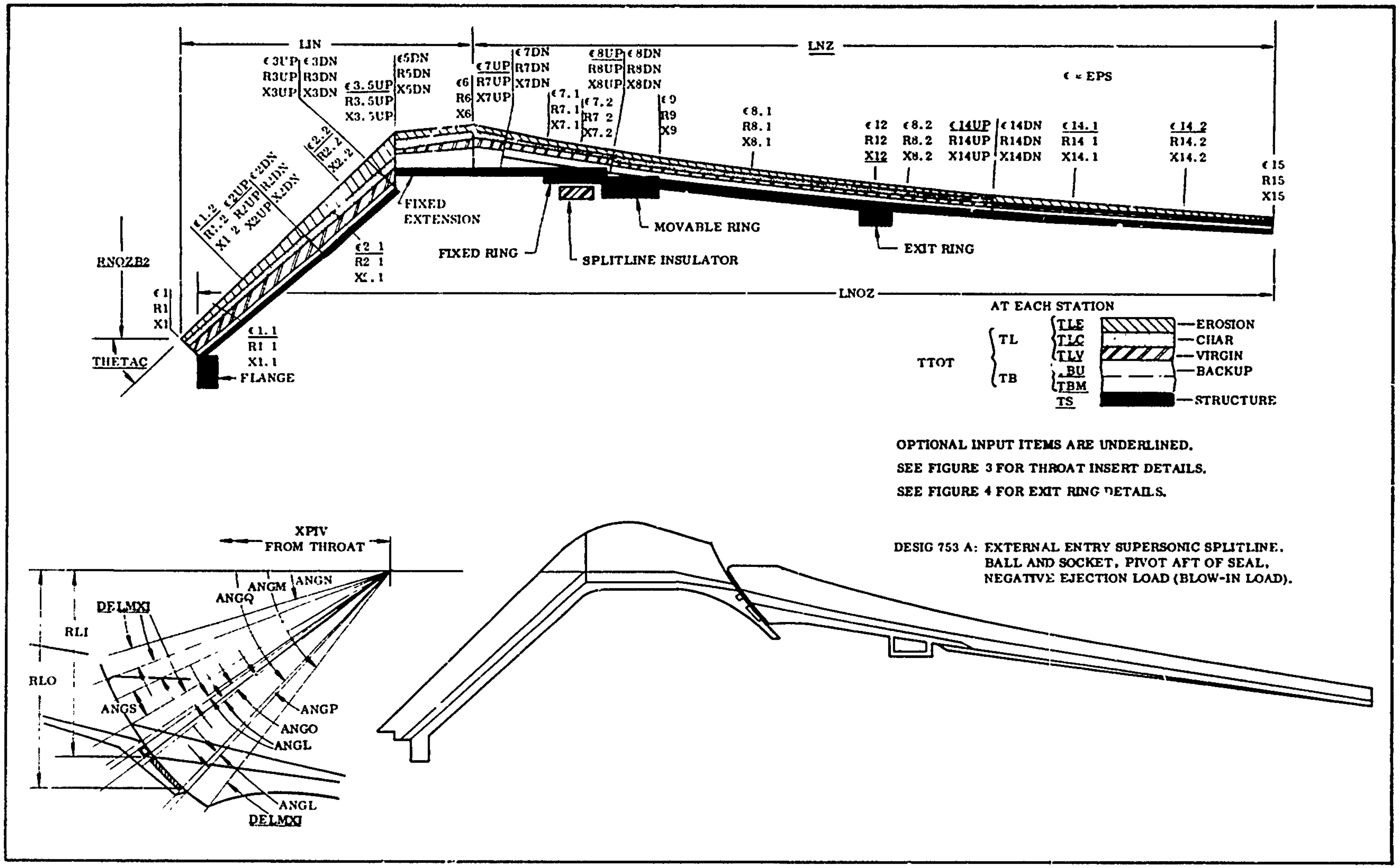


Figure 39. Nozzle DESIG 753A Diagram

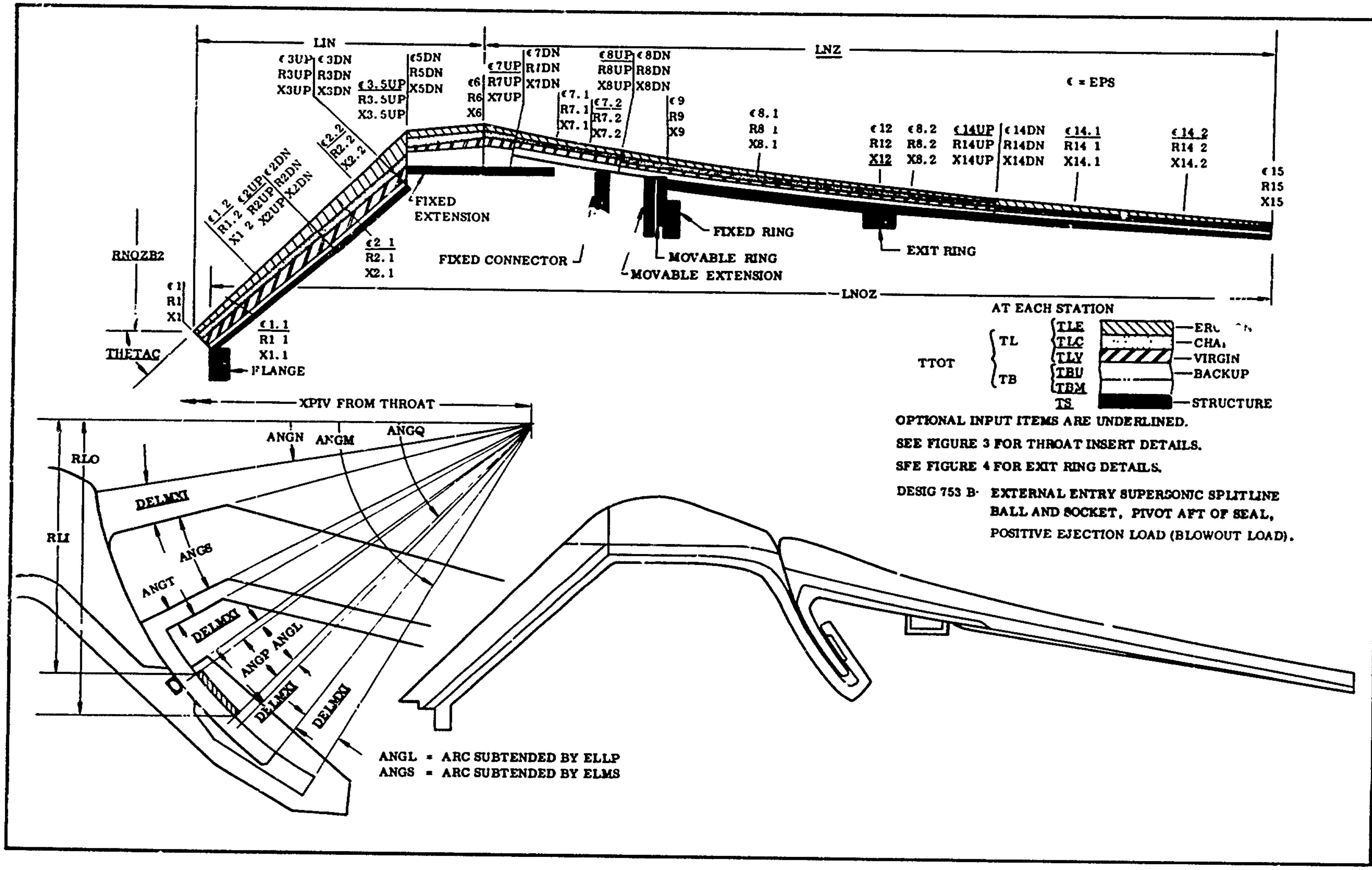


Figure 40. Nozzle DESIG 753B Diagram

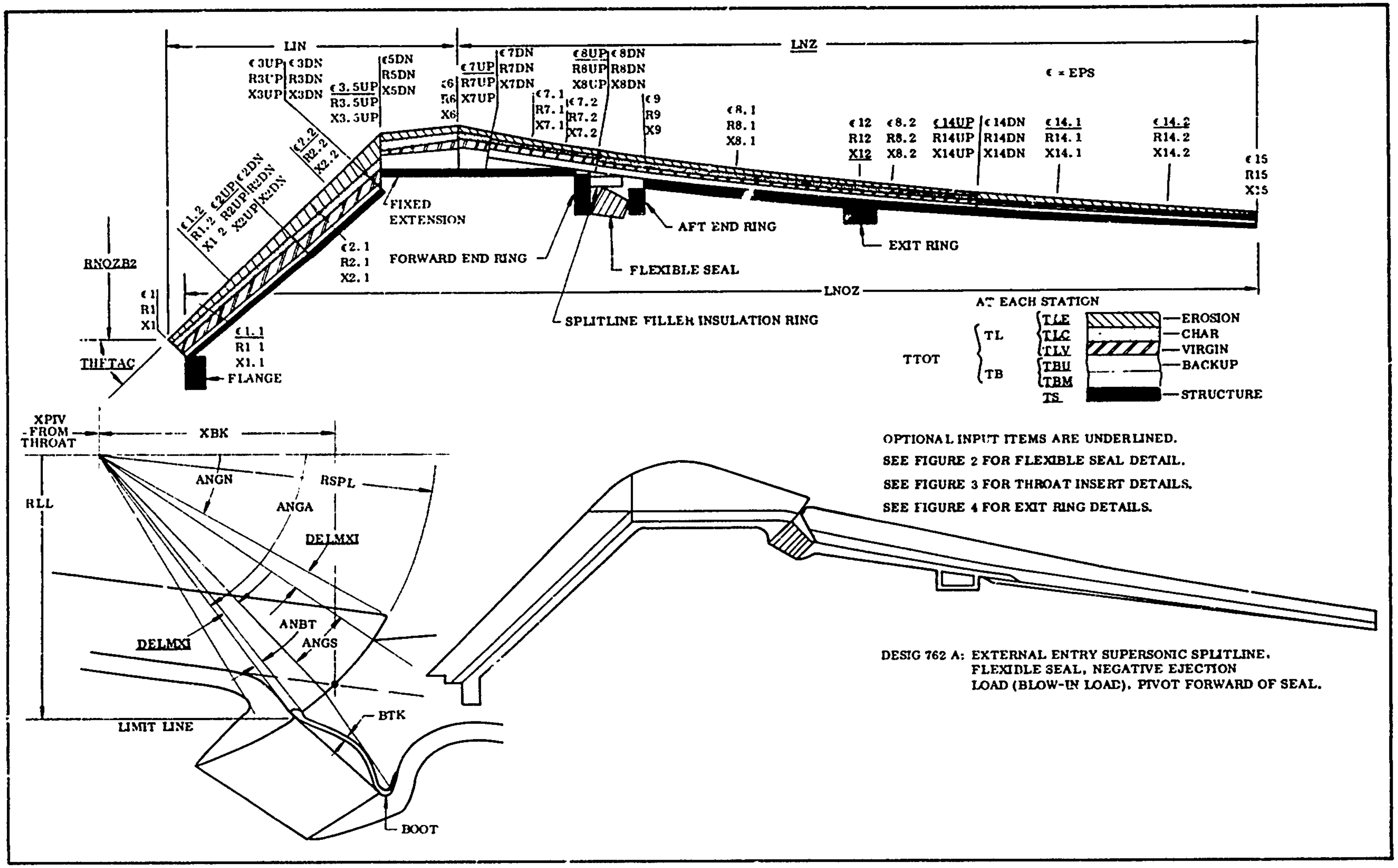


Figure 41. Nozzle DESIG 762A Diagram

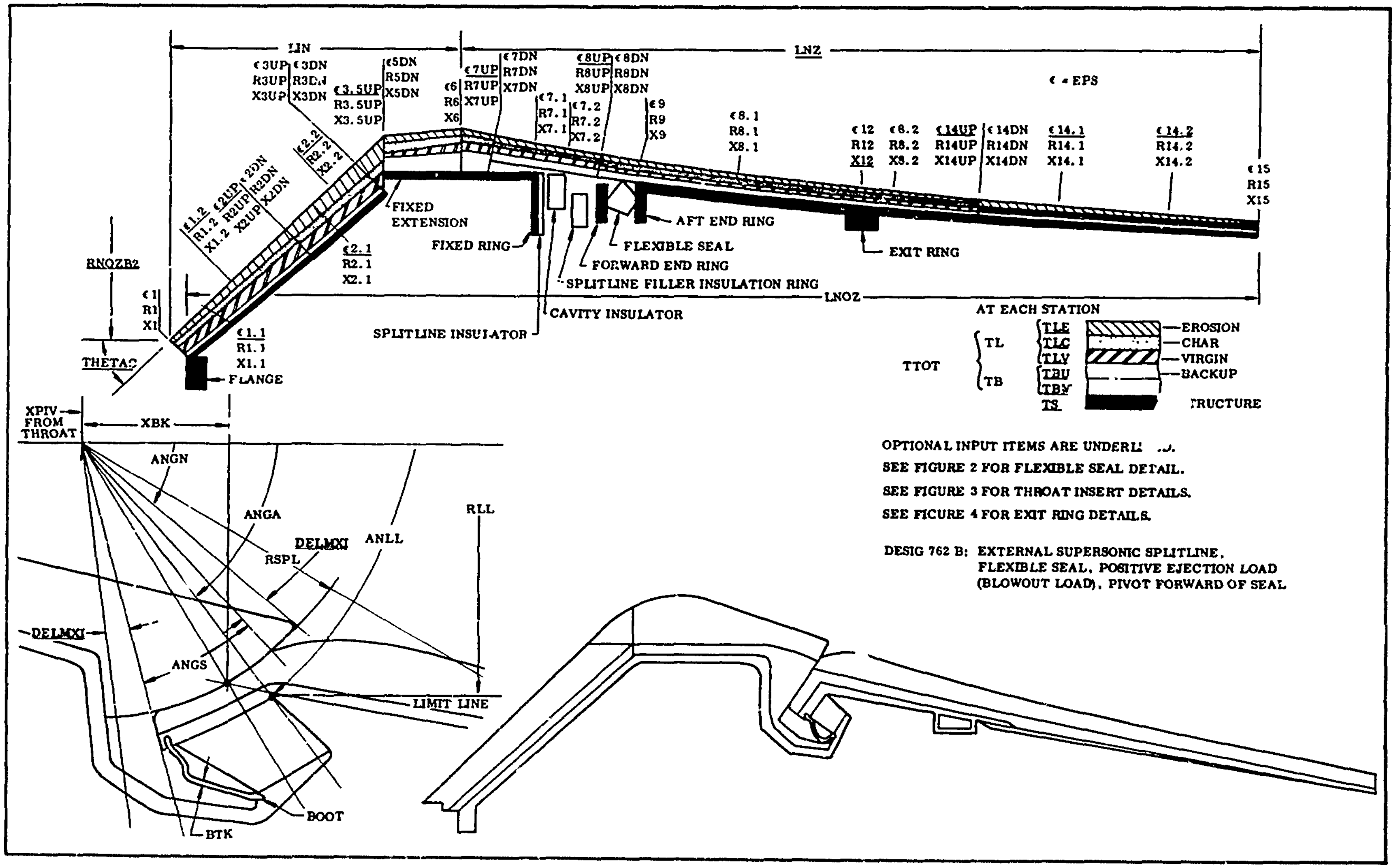


Figure 42. Nozzle DESIG 762B Diagram

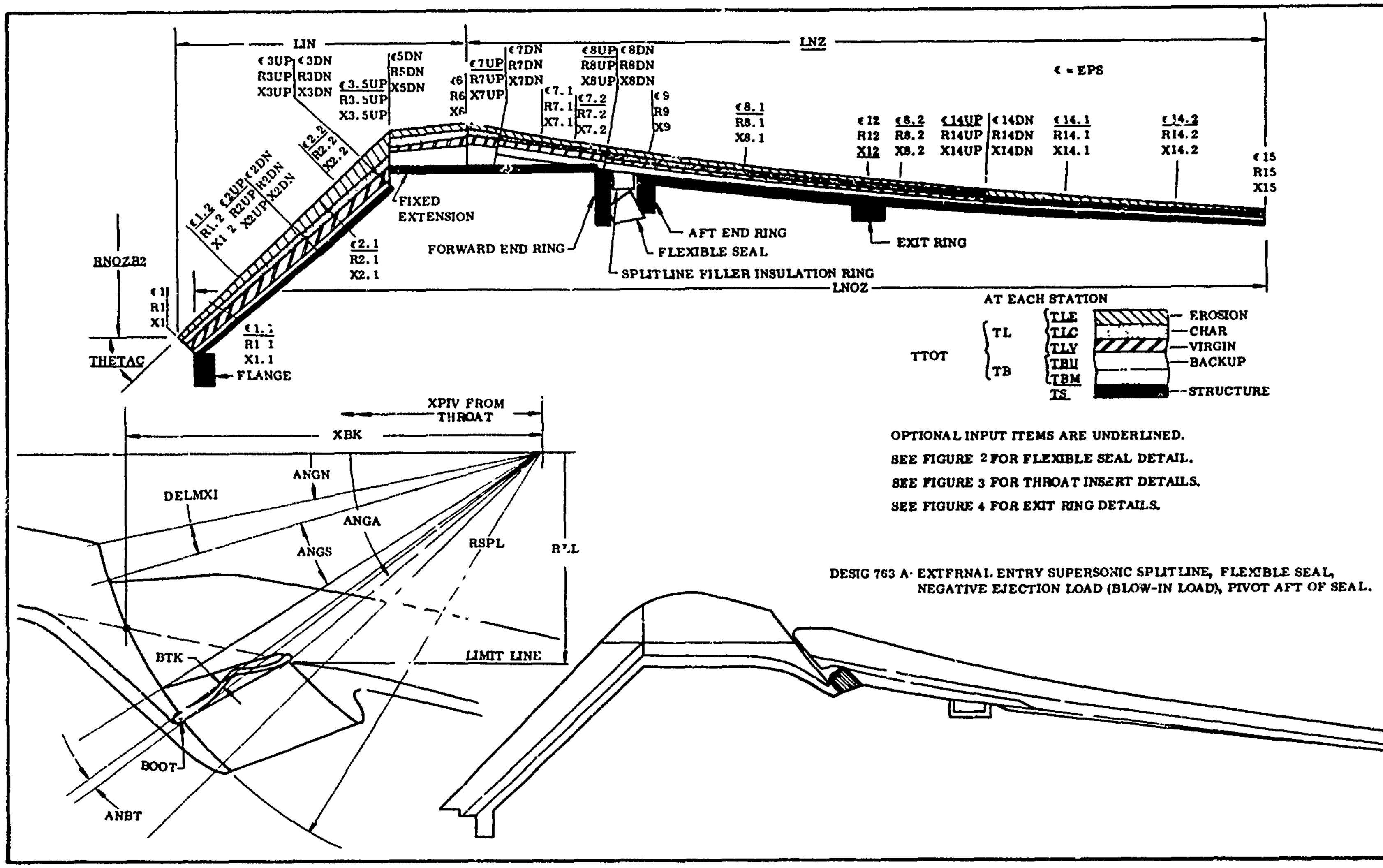


Figure 43. Nozzle DESIG 763A Diagram-

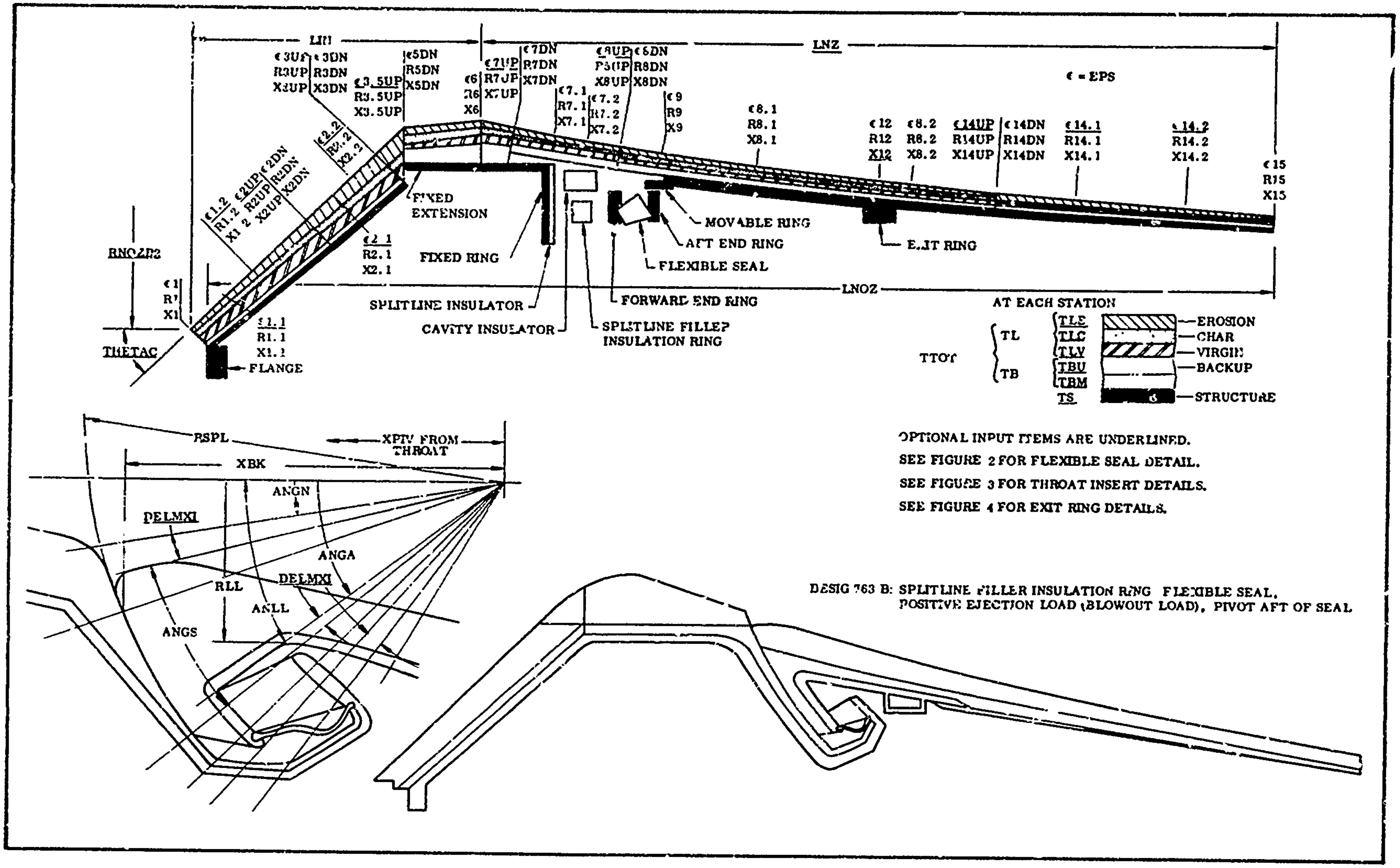


Figure 44. Nozzle DESIG 763B Diagram

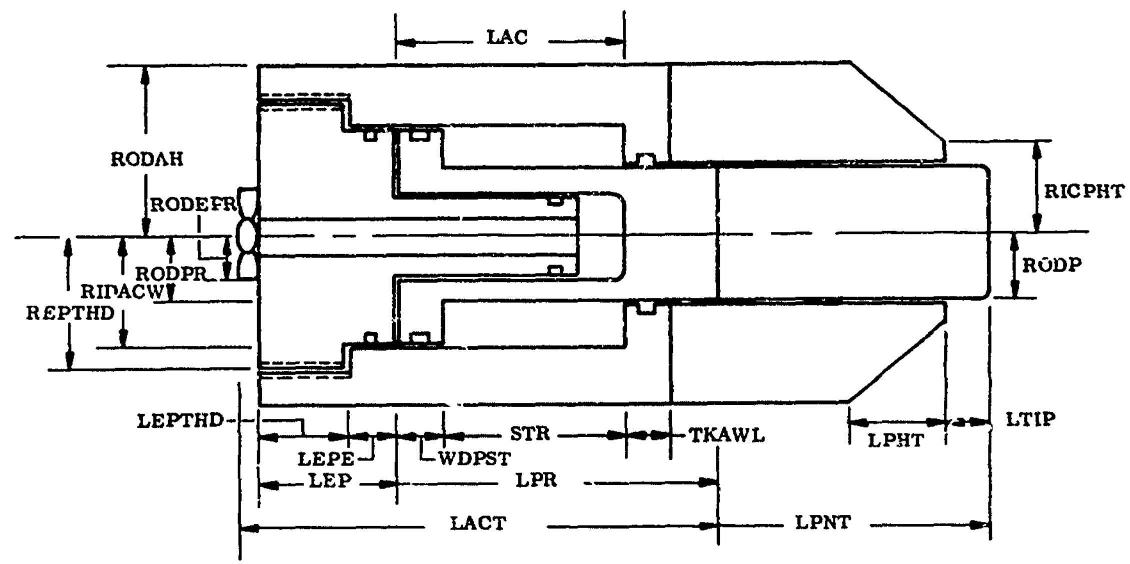


Figure 45. Solid Tungsten Pintle and Actuator

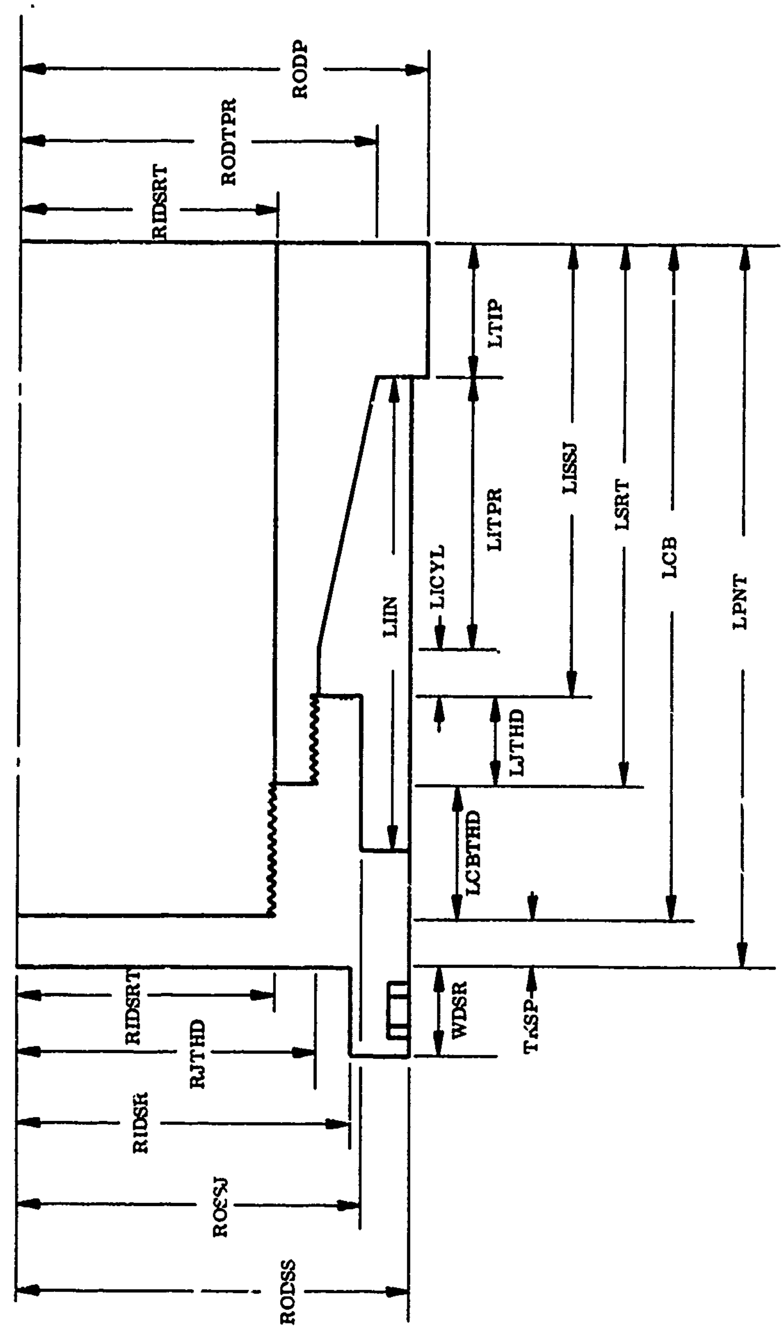


Figure 46. Tungsten Shell Pintle

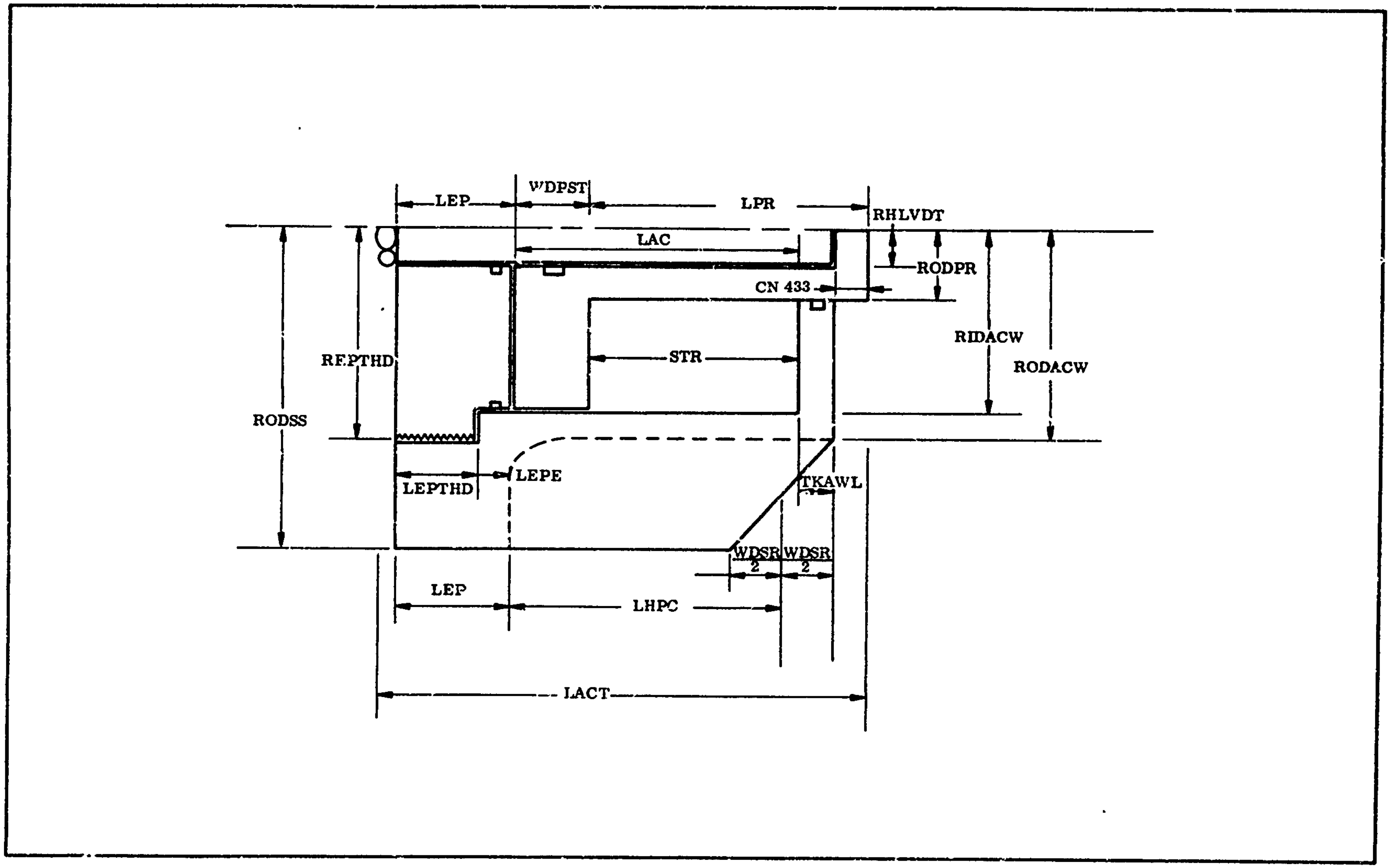


Figure 47. Actuator for Tungsten Shell Pintle

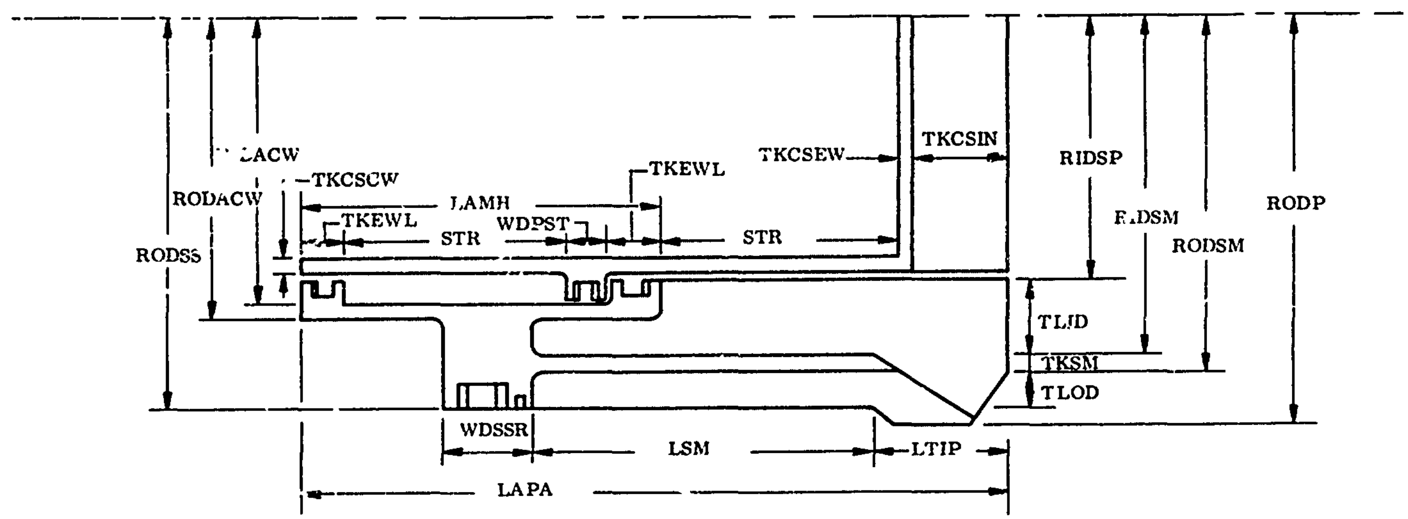


Figure 48. Ablative Sleeve Pintle and Actuator

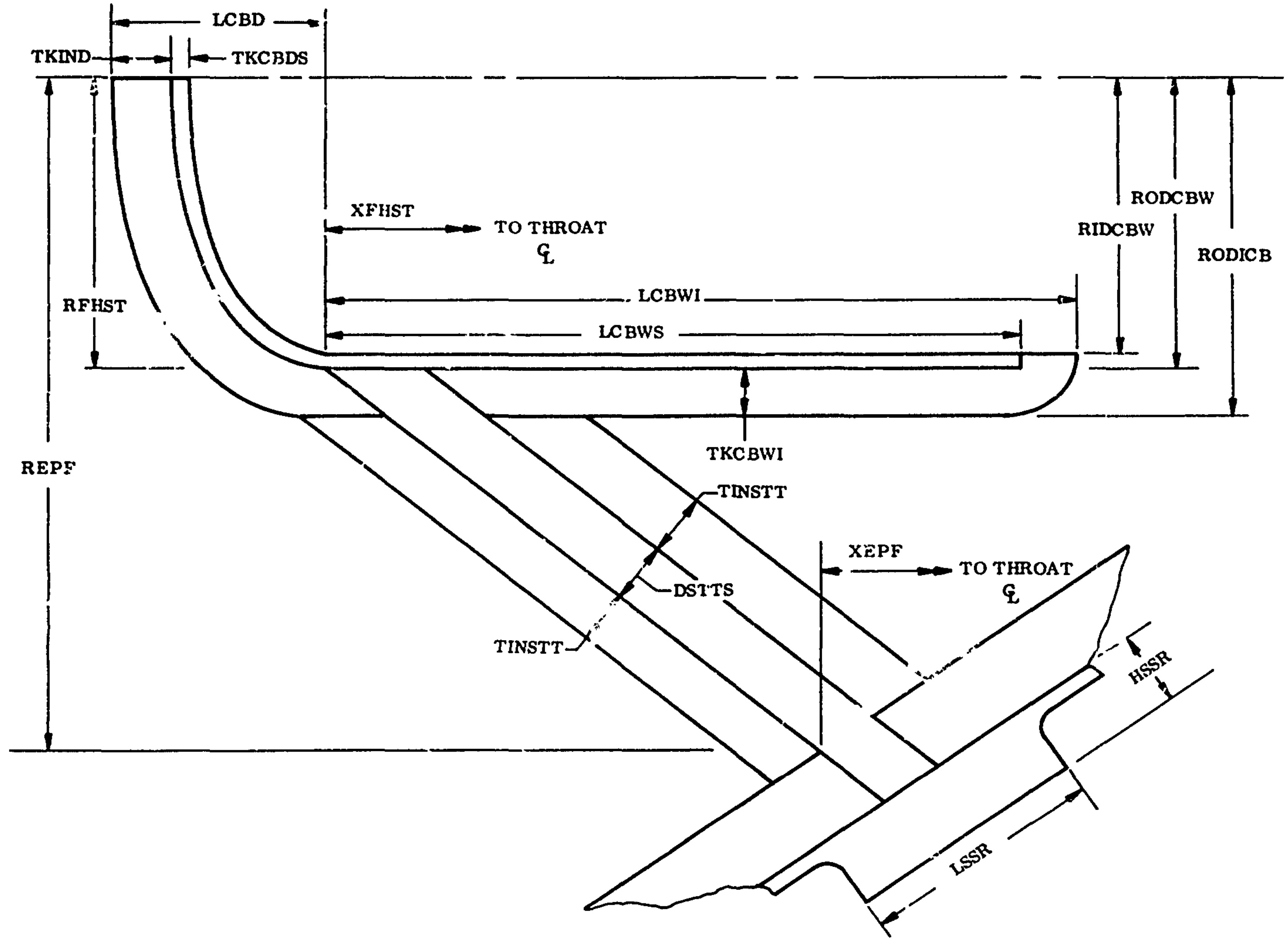


Figure 49. Strutted Centerbody

SECTION V

TRAJECTORY REFLY

If the user wishes to simulate the vehicle trajectory after the hardware design subroutines have evaluated the TVC system hardware weights and thrust perturbations, the refly option can be used. Essentially the same data are necessary for the trajectory refly as for the original trajectory simulation. All data input in the previous trajectory input are available for the refly option; however, any data read in by cards for the refly option will supersede the data stored previously. Thus, any data can be modified for the refly of the trajectory. Typical of data that might be changed for the refly would be a change in print interval.

APPENDIX A

TRAJECTORY OUTPUT DEFINITIONS

Printout formats, both schematic and machine printed, for output print are presented in this appendix. The X's and O's shown in the schematic formats represent spaces for integers and minus signs, respectively. The numbers and letters appearing at the left side of the printlines are always printed with their respective printline. The definitions of these output parameters are present as they appear left to right for each printline.

Output Print Format I

Main Print

	t	S	h	V_e	V_I	a_{xb}	M_y	T_y
A	XXXX.XXXX	XXXXXXXXX.	XXXXXXXX.	XXXXX.XXX	XXXXX.XXX	0XX.XXXXX	XX	XX
	S_s	S_c	ϕ	ζ				
AA	XXXXXXXXX.	XXXXXXXXX.	0XXX.XXXX	0XXX.XXX				
	θ_m	$\dot{\theta}_m$	α	γ_1	γ_{1I}	a_{zb}	$\dot{V}_e$	
B	0XX.XXXX	0XX.XXXXX	0XXX.XXXX	0XXX.XXXX	0XXX.XXXX	0XX.XXXXX	0XXXX.XX	
	ψ_m	$\dot{\psi}_m$	β	γ_2	γ_{2I}	a_{Yb}	η_{bt}	
BA	0XXX.XXXX	0XX.XXXXX	0XXX.XXXX	XXX.XXXX	0XXX.XXXX	0XX.XXXXX	0XX.XXX	
	ϕ_m	$\dot{\phi}_m$	P_m	Q_m	R_m	μ	ρ	
BB	0XXX.XXXX	0XX.XXXXX	0XX.XXXXX	0XX.XXXXX	0XX.XXXXX	0XXX.XXXX	0XX.XXXX	
	W	$\dot{W}$	F	F_V	$[F/\dot{W}]$	F_x	η_{bn}	
C	XXXXXXXXX.	XXXXXX.XX	0XXXXXXXX.	0XXXXXXXX.	XXXX.XXXX	0XXXXXXXX.	0XX.XXX	
	$\dot{I}_{YY}$	M_{DQ}	M_{cQ}	M_{FCQ}	M_{JDQ}	F_{JDz}	M_{IQ}	
CA	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXX	
	$\dot{I}_{ZZ}$	M_{DR}	M_{CR}	M_{FCR}	M_{JDR}	F_{JDy}	M_{IR}	
CB	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXX	
	P_c	P_e	P^*	P_s	ϵ_s			
CC	0XXXXXXX.XX	0XXXXXXX.XX	0XXXXXXX.XX	0XXXXXXX.XX	0XXX.XXXXX			
	$\dot{I}_{xx}$	M_{DP}	M_{CP}	M_{FCP}	M_{FVP}	M_{FOP}	M_{IP}	
CD	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXX	
	r_b	D_b	g_{WI}	V_{CI}	A_{SI}	ϵ_d	C_{FI}	
CE	XX.XXXXXX	XXXX.XXXX	X.XXXXX	XXXXXXXXX.	XXXXXXX.X	XXXX.XXXX	X.XXXXXXX	
	$\dot{P}_c$	P_c	P_{cc}	F_{com}	F_{CV}	F_{VN}	F_N	
CF	±XXXXXXXX.	XXXXX.XXX	XXXXX.XXX	XXXXXXXX.	XXXXXXXX.	XXXXXXXX.	XXXXXXXX	
	$\dot{a}_t$	A_t	A_{tcc}	K_s	K_p	ω_p		
CG	±XXXXXX.X	XXXX.XXXX	XXXX.XXXX	XXXX.XXXX	XXXX.XXXX	XXXX.XXXX		
	$\dot{W}_{MP}$	W_{pr}	g_{PI}	A_{xl}				
CH	XXXXXX.XX	XXXXXXXX.	X.XXXXX	XXXX.XXXX				

Printline	Symbol	Definition	Units
A	t	Instantaneous time (L5000)	(sec)
	S	Missile ground range. Distance along the surface of the earth measured clockwise from the launch vertical to the local vertical down range (L5018)	(ft)
	h	Missile geometric altitude. Distance between the surface of the reference body and the missile measured along the local vertical. Positive away from the reference body (L5028)	(ft)
	V_e	Missile earth referenced velocity (L5046)	(ft/sec)
	V_I	Missile intertial velocity (L5050)	(ft/sec)
	a_{Xb}	Component of vehicle acceleration due to total thrust and aerodynamic forces. Positive in the direction of the coordinate axes of b system (L5504)	(g's)
	M_y	Mode type	(dim)
	T_y	Type of flight	(dim)
AA	S_s	Missile slant ground range. Distance along earth surface from the launch vertical to the local vertical slantwise (L5025)	(ft)
	S_c	Missile cross ground range. Distance along the surface of the earth measured clockwise from launch azimuth (L5028)	(ft)
	Φ	Instantaneous down range angle. Angle between the launch vertical and the local vertical on the down range azimuth point (L5375)	(deg)
	ζ	Cross range angle. Angle between local vertical and vertical on firing azimuth down range location. Positive if positive is left of firing azimuth (L5358)	(deg)
B	θ_m	Desired missile attitude Euler angle relating the m and i system (L5722)	(deg)

Printline	Symbol	Definition	Units
B	$\dot{\theta}_m$	Desired vehicle pitch Euler angular rate (5772)	(deg/sec)
	α	Instantaneous pitch angle of attack; positive if the vehicle centerline is above the air velocity vector (L5301)	(deg)
	γ_1	Pitch flight path angle. Angle between the earth referenced velocity vector and the local tangent plane. Positive away from the earth (L5321)	(deg)
	γ_{1I}	Inertial pitch flight path angle. Angle between the inertial velocity vector and the local tangent plane. Positive away from the earth (L5330)	(deg)
	a_{Zb}	Components of vehicle acceleration due to total thrust and aerodynamic forces. Positive in the direction of the coordinate Z axes of b system (L5506)	(g's)
	$\dot{V}_e$	Time rate change of missile earth reference velocity (L5047)	(ft/sec^2)
BA	ψ_m	Desired missile attitude Euler angle relating the m and i systems (L5723)	(deg)
	$\dot{\psi}_m$	Desired vehicle yaw Euler angular rate (L5773)	(deg/sec)
	β	Angle of side slip. Positive if the vehicle centerline is left of the air velocity vector when viewed from the rear of the vehicle (L5315)	(deg)
	γ_2	Azimuthal flight path angle. Angle between the horizontal projection of the earth reference velocity vector and the local north. Positive clockwise from north (L5323)	(deg)
	γ_{2I}	Inertial azimuth flight path angle. Angle between local north clockwise to the projection of the inertial velocity vector on the local tangent plane (L5331)	(deg)

Printline	Symbol	Definition	Units
BA	a_{Yb}	Component of vehicle acceleration due to total thrust and aerodynamic forces. Positive in the direction of the coordinate Y axes of the b system (L5505)	(g's)
	η_{bt}	Acceleration load factor transverse to the velocity vector (L5170)	(g's)
BB	ϕ_m	Desired missile attitude Euler angle relating the m and i systems (L5724)	(deg)
	$\dot{\phi}_m$	Desired vehicle roll Euler angular rate (L5774)	(deg/sec)
	P_m	Instantaneous desired roll turning rate (L5403)	(deg/sec)
	Q_m	Instantaneous desired pitch turning rate (L5401)	(deg/sec)
	R_m	Instantaneous desired yaw turning rate (L5402)	(deg/sec)
	μ	Instantaneous vehicle longitude. Value is positive or negative west or east of Greenwich, England, respectively (L5362)	(deg)
	ρ	Instantaneous vehicle latitude positive north of the equator $-90° \leqq \rho \geqq$ (L5367)	(deg)
C	W	Total instantaneous missile weight (L5093)	(lb)
	$\dot{W}$	Total expended instantaneous missile mass flow weight (L5094)	(lb/sec)
	F	Total instantaneous thrust acting along missile centerline. Positive when thrust vector points forward along missile centerline (L5122)	(lb)
	F_v	Instantaneous total vacuum thrust (L5123)	(lb)
	$\lvert F/\dot{W} \rvert$	Instantaneous effective specific impulse (L5115)	(sec)
	F_x	Components of total vehicle thrust parallel to the coordinate axes of the b system (L5141)	(lb)

Printline	Symbol	Definition	Units
	η_{bn}	Acceleration load factor normal to the velocity vector (L5171)	(g's)
CA	$\dot{I}_{YY}$	Time rate change of pitch moment of inertia	(ft-lb-sec)
	M_{DQ}	Perturbing moment about vehicle center-of-gravity in pitch (L5205)	(ft-lb)
	M_{CQ}	Controlling moment about vehicle center-of-gravity in pitch (L5208)	(ft-lb)
	M_{FCQ}	Thrust vector control pitching moment (L5223)	(ft-lb)
	M_{JDQ}	Jet damping pitching moment (L5220)	(ft-lb)
	F_{JDz}	Jet damping pitching transverse force (L5149)	(lb)
	M_{IQ}	Unbalanced pitching moment about vehicle center-of-gravity (L5202)	(ft-lb)
CB	$\dot{I}_{ZZ}$	Time rate change of yaw moment of inertia (L5192)	(ft-lb-sec)
	M_{DR}	Perturbing moment about vehicle center-of-gravity in yaw (L5206)	(ft-lb)
	M_{CR}	Controlling moment about vehicle center-of-gravity in yaw (L5209)	(ft-lb)
	M_{FCR}	Thrust vector control yawing moment (L5224)	(ft-lb)
	M_{JDR}	Jet damping yawing moment (L5221)	(ft-lb)
	F_{JDy}	Jet damping yawing transverse force (L5149)	(lb)
	M_{IR}	Unbalanced yaw moment about vehicle center-of-gravity (L5[illegible])	(ft-lb)
CC	P_c	Main motor chamber pressure used in separated flow equation (L5734)	(lb/in^2)
	P_e	Main motor exit pressure used in separated flow equations (L5074)	(lb/ft^2)

Printline	Symbol	Definition	Units
CC	P^*	Main motor nozzle critical pressure used in separated flow equations (L5072)	(lb/in^2)
	P_s	Main motor nozzle separation pressure used in separated flow equations (L5073)	(lb/in^2)
	ϵ_s	Main motor nozzle separation expansion ratio used in separated flow equations (L5075)	(dim)
CD	$\dot{I}_{XX}$	Time rate change of roll moment of inertia (L5184)	(ft-lb-sec)
	M_{DP}	Perturbing moment about vehicle center-of-gravity in roll (L5207)	(ft-lb)
	M_{CP}	Controlling moment about vehicle center-of-gravity in roll (L5210)	(ft-lb)
	M_{FCP}	Auxiliary roll thrust control moment (L5225)	(ft-lb)
	M_{FVP}	Rolling moment about vehicle center-of-gravity due to vortexing effect of axial gas flow through the nozzle (L5219)	(ft-lb)
	M_{FOP}	Thrust offset rolling moment due to pitch and yaw TVC (L5216)	(ft-lb)
	M_{IP}	Unbalanced roll moment about vehicle center-of-gravity (L5204)	(ft-lb)
CE	r_b	Propellant burn rate (L5783)	(in/sec)
	D_b	Propellant burn depth. Used in TMC logic (L5733)	(in)
	g_{WI}	Percent web (L5077)	(dim)
	V_{cI}	Chamber volume (L5078)	(in^3)
	A_{SI}	Burn surface area (L5079)	(in^2)
	ϵ_d	Input and output nozzle expansion ratio used in the separated flow nozzle thrust equations (Lk013)	(dim)
	C_{FI}	Thrust coefficient (Lk5081)	(dim)

Printline	Symbol	Definition	Units
CF	$\dot{P}_C$	Time rate change of chamber pressure (L5784)	$(lb/in^2\text{-}sec)$
	P_{cc}	Commanded chamber pressure used in pintle motor control logic (L5071)	(lb/in^2)
	F_{com}	Commanded altitude thrust used in TMC logic (L5130)	(lb)
	F_{CV}	Commanded vacuum thrust used in TMC logic (L5131)	(lb)
	F_{VN}	Nominal vacuum thrust used in TMC logic (L5132)	(lb)
	F_N	Nominal altitude thrust used in TMC logic	(lb)
CG	$\dot{a}_t$	Time rate change of pintle throat area (L5785)	(in^2/sec)
	A_t	Pintle nozzle throat area. Used in TMC logic (L5735)	(in^2)
	A_{tcc}	Commanded throat area (L5080)	(in^2)
	K_S	Pressure error gain used in pintle area control low in the TMC (L5450)	$(in^4/lb\text{-}sec)$
	K_p	Pressure rate gain used in pintle area control low in the TMC (L5451)	(sec)
	ω_p	Pintle control frequency (L5083)	(rad/sec)
CH	$\dot{W}_{MP}$	Mass flow rate of gases thru pintle nozzle throat (L5786)	(lb/sec)
	W_{pr}	Weight of propellant removed. Used in TMC logic (L5736)	(lb)
	g_{PI}	Fraction of propellant removed (L5084)	(dim)
	A_{XI}	Propellant extinguishment throat area (L5085)	(in^2)

OUTPUT PRINT FORMAT I

MAIN PRINT

	$\hat{F}_c$	K_{cv}	V_{XXX}	$\dot{V}_{XXX}$	K_{XXX}	
CI	XXXXXXXX.	XXXX.XXXX	XXXXX.XXX	OXXXX.XX	XXXX.XXXX	
	F_{cqmin}	F_{cqmax}	K_{cq}	$\dot{V}_{ecq}$	F_{cALOS}	F_{cclos}
CJ	XXXXXXXX.	XXXXXXXXX.	XXXX.XXXX	OXXXX.XX	XXXXXXXX.	XXXXXXXX.

where:

$$V_{XXX} = \begin{cases} V_{ecv} & \text{If } F_y = 1 \\ V_{ecm} & \text{If } F_y = 2 \\ V_{cv} & \text{If } F_y = 4 \\ 0 & \text{Otherwise} \end{cases}$$

$$\dot{V}_{XXX} = \begin{cases} \dot{V}_{ecv} & \text{If } F_y \quad 1 \\ \dot{V}_{ecm} & \text{If } F_y \quad 2 \\ 0 & \text{Otherwise} \end{cases}$$

$$K_{XXX} = \begin{cases} K_{CPR} & \text{If } F_y = 3 \\ K_{ALOS} & \text{If } F_y = 6 \\ 0 & \text{Otherwise} \end{cases}$$

Printline	Symbol	Definition	Units
CI	$\hat{F}_c$	Thrust required to maintain V_e; i.e., retarding axial force used in TMC logic (L5134)	(lb)
	K_{cv}	Commanded thrust velocity error gain used in TMC (L5452)	(lb-sec/ft)
	V_{xxx}	Command velocity used in the TMC command logic. V_{ecv} if Fy = 1, V_{ecm} if Fy = 4 (L5060)	(ft/sec^2)
	$\dot{V}_{xxx}$	Command acceleration used in the TMC command logic. $\dot{V}_{ecv}$ if Fy = 1, $\dot{V}_{ecm}$ if Fy = 2, and zero if Fy = 1 and Fy = 2 (L5061)	(ft/sec^2)
	[illegible]X	Commanded thrust system gain. Set equal to K_{CPR} if Fy = 3 and K_{ALOS} if Fy = 6 (L5454)	(dim)
CJ	F_{cqmin}	Require thrust so that the vehicle will maintain the minimum dynamic pressure used in TMC logic (L5135)	(lb)
	F_{cqmax}	Maximum thrust so that the vehicle will not exceed the maximum dynamic pressure used in TMC logic (L5136)	(lb)
	K_{cq}	Commanded thrust dynamic pressure error gain used in TMC (L5453)	(ft^2)
	$\dot{V}_{ecq}$	Command acceleration to constrain dynamic pressure used in the TMC command logic (L5062)	(ft/sec^2)
	F_{CALOS}	Command thrust to provide acceleration proportional to LOS rated used in TMC logic (L5137)	(lb)
	F_{cclos}	Command thrust to provide a minimum missile to target closing rate used in TMC logic (L5138)	(lb)
D	M	Missile Mach number (L5063)	(dim)
	q	Missile dynamic pressure (L507[illegible])	(lb/ft^2)
	V_a	Missile velocity with respect to air (L5049)	(ft/sec)

	M	q	V_a	C	N_Z	$q\alpha'$	Pa
D	XX.XXXXX	XXXXX.XX	0XXXXX.XX	XXXXXX.XX	0XXXXXXXX	XXXXXX.X	XXXX.XX
	$\dot{\alpha}$	$\bar{\alpha}$	$\mathring{\bar{\alpha}}$	α'	$[illegible]_w$	V_w	$\dot{V}_w$
DA	0XXXX.XXX	0XXX.XXXX	0XXX.XXXX	0XXX.XXXX	XXX.XXXXX	0XXX.XXX	0XXXX.XXX
	$\dot{\beta}$	$\bar{\beta}$	$\mathring{\bar{\beta}}$	$\bar{\alpha}'$	[illegible]	[illegible]	$[illegible]_c$
DB	0XXXX.XXX	0XXX.XXXX	0XXX.XXXXX	0XXX.XXXX	XXX.XXXXX	0XXX.XXX	0XXX.XXX
	x_{cp}	M_{NQ}	l_{cp}	M_{NSQ}	M_{CZG}	M_{NDQ}	N_{Pz}
DC	0XXXX.XXXX	0XXXXXXXX.	0XXX.XXXX	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.	0XXXXXXXX.
	M_{NP}	M_{NR}	M_{RAP}	M_{NSR}	M_{CYG}	M_{NDR}	N_{Py}
DD	0XXXXXXX.	0XXXXXXXX.	0XXXXXXX.	0XXXXXXXX.	0XXXXXXX.	0XXXXXXXX.	0XXXXXXXX.
	$M_{\delta Q}$	$l_{\delta z}$	$N_{\delta z}$	$C_{\delta z}$	M_{hz}	l_{hz}	U_{cz}
DE	0XXXXXXXX.	0XXXX.XXXX	0XXXXXXXX.	0XXXXXX.XX	0XXXXXXXX.	0XXXX.XXXX	0XXXXXX.
	$M_{\delta R}$	$l_{\delta y}$	$N_{\delta y}$	M_{hy}			
DF	0XXXXXXXX.	0XXXX.XXX	0XXXXXXXX.	0XXXXXXXX.			
	I_{YY}	z_e	x_{cg}	z_{cg}	θ_b	Q_b	$\dot{Q}_b$
E	XXXXXXXXX.	0XX.XXXX	XXXX.XXXX	0XXX.XXXX	0XXX.XXXX	0XX.XXXX	0XXX.XXXX
	I_{ZZ}	y_e	y_{cg}	ψ_b	R_b	$\dot{R}_b$	
EA	XXXXXXXXX.	XXXX.XXXX	0XXX.XXXX	0XXX.XXXX	0XX.XXXX	0XXX.XXX	
	I_{XX}	ϕ_b	$\dot{\phi}_b$	P_b	$\dot{P}_b$		
EB	XXXXXXXXX.	0XX.XXXXX	0XXX.XXXX	0XX.XXXX	0XXX.XXX		
	δ_{Pc}	δ_P	$\dot{\delta}_P$	$\ddot{\delta}_P$	F_z	K_{DP}	K_{RP}
F	0XX.XXXXX	0XX.XXXXX	0XXX.XXXXX	0XXXX.XX	0XXXXXX.XX	XXXX.XXX	XXX.XXXX
	δ_{Yc}	δ_Y	$\dot{\delta}_Y$	$\ddot{\delta}_Y$	F_y	K_{DY}	K_{RY}
FA	0XX.XXXXX	0XX.XXXXX	0XXX.XXXXX	0XXXX.XX	0XXXXXX.XX	XXXX.XXX	XXX.XXXX
	$\bar{\delta}_P$	I_P	$I_{\dot{\delta}P}$	M_{FOQ}	$\Delta\theta_b$	M_{TDQ}	F_{TDz}
FB	0XX.XXXXX	XXXXXXXXX.	XXXXX.XX	0XXXXXXXX.	0XX.XXXX	0XXXXXXXX.	0XXXXXX.
	$\bar{\delta}_Y$	I_Y	$I_{\dot{\delta}Y}$	M_{FOR}	$\Delta\psi_b$	M_{TDR}	F_{TDy}
FC	0XX.XXXXX	XXXXXXXXX.	XXXXX.XX	0XXXXXXXX.	0XXX.XXXX	0XXXXXXXX	0XXXXXXX
	F_c	I_R	F_D	$\Delta\phi_b$	F_R	$\dot{F}_R$	$\dot{W}_R$
FD	0XXXXXX.X	XXXXXXXXX	0X.XXXXXX	0XXX.XXXX	0XXXXXX.X	0XXXXX.XX	0XXXXX.X
	t_T	S_T	h_T	V_T	γ_T	a_{TT}	a_{TN}
G	XXXX.XXXX	XXXXXXXXX.	XXXXXXXX.	XXXXX.XXX	0XX.XXXX	0XX.XXXXX	0XX.XXXXX
	S_{TC}	γ_M	$\dot{\gamma}_M$	ζ_T	a_{TC}		
GA	XXXXXXXXX.	0XXX.XXXXX	0XXXXX.XXXX	0XX.XXXXX	0XX.XXXXX		

Printline	Symbol	Definition	Units
D	C	Instantaneous aerodynamic axial force (L5164)	(lb)
	N_Z	Instantaneous pitch aerodynamic normal forces directed opposite to the direction of the Z_b axes (L5166)	(lb)
	$q\alpha'$	Product of total angle of attack and dynamic pressure (L5110)	(lb/deg/ft^2)
	P_a	Ambient pressure at the missile (L5068)	(lb/ft^2)
DA	$\dot{\alpha}$	Time rate change of angle of attack (L5302)	(deg/sec)
	$\bar{\alpha}$	Still wind angle of attack (L5310)	(deg)
	$\dot{\bar{\alpha}}$	Time rate change of still wind angle of attack (L5307)	(deg/sec)
	α'	Total vehicle angle of attack; angle between the centerline of the vehicle and the missile air velocity vector; always positive (L5309)	(deg)
	ψ_w	Instantaneous wind azimuth angles, measured in a plane parallel to the local tangent plane where j = 1, 2, ..., 30. Angle measured clockwise from north to the direction from which the wind is coming (L5383)	(deg)
	V_w	Instantaneous wind speed change (L5056)	(ft/sec)
	$\dot{V}_w$	Instantaneous wind speed time rate change (L5057)	(ft/sec)
DB	$\dot{\beta}$	Time rate change of angle of side slip (L5316)	(deg/sec)
	$\bar{\beta}$	Still wind angle of side slip (L5318)	(deg)
	$\dot{\bar{\beta}}$	Time rate change of still wind angle of side slip (L5308)	(deg/sec)
	$\bar{\alpha}'$	Still air total angle of attack (L5305)	(deg)

Printline	Symbol	Definition	Units
DB	ϵ	Total angle of attack roll orientation angle. Angle between total angle of attack plane and yaw axis. Measured counterclockwise (L5353)	(deg)
	φ	Local bank angle (L5380)	(deg)
	φ_c	Commanded bank angle (L5377)	(deg)
DC	x_{cp}	Input and instantaneous (with Mach number M) aerodynamic normal force center of pressure body station numbers, respectively, where j = 1, 2, ..., 15 per stage respectively (L5583)	(ft & dbi)
	M_{NQ}	Aerodynamic yawing moment about vehicle center-of-gravity (L5211)	(ft-lb)
	l_{cp}	Vehicle center-of-gravity to aerodynamic center-of-pressure distance (L5596)	(ft)
	M_{NSQ}	Aerodynamic static pitching moment about vehicle center-of-gravity (L5332)	(ft-lb)
	M_{CZG}	Aerodynamic axial force center-of-gravity offset pitching moment (L5230)	(ft-lb)
	M_{NDQ}	Aerodynamic damping moment about vehicle vehicle center-of-gravity in pitch (L5235)	(ft-lb)
	N_{PZ}	Aerodynamic force due to damping and pitch (L5168)	(lb)
DD	M_{NP}	Aerodynamic rolling moment about vehicle center-of-gravity (L5213)	(ft-lb)
	M_{NR}	Aerodynamic yawing moment about vehicle center-of-gravity (L5212)	(ft-lb)
	M_{RAP}	Aerodynamic rolling moment induced by raceways (L5222)	(ft-lb)
	M_{NSR}	Aerodynamic static yawing moment about vehicle center-of-gravity (L5233)	(ft-lb)
	M_{CYG}	Aerodynamic axial force center-of-gravity offset yawing moment (L5229)	(ft-lb)
	M_{NDR}	Aerodynamic damping moment about vehicle center-of-gravity in yaw (L5236)	(ft-lb)

Printline	Symbol	Definition	Units
DD	N_{PY}	Aerodynamic force due to damping in yaw (L5167)	(lb)
DE	$M_{\delta Q}$	Pitching moment due to the aerodynamic control force (L5226)	(ft-lb)
	$l_{\delta z}$	Pitch movable control fin center-of-pressure to vehicle center-of-gravity lever arm (L5601)	(ft)
	$N_{\delta z}$	Aerodynamic pitch fin normal force (L5157)	(lb)
	$C_{\delta z}$	Aerodynamic pitch fin axial force (L5155)	(lb)
	M_{hz}	Torque about the pitch fin hinge axis (L5248)	(ft-lb)
	l_{hz}	Pitch movable control fin center-of-pressure to hinge axis lever arm (L5602)	(ft)
	U_{cz}	Output pitch aerodynamic control fin center-of-pressure as a ratio of fin chord length (L5568)	(dim)
DF	$M_{\delta R}$	Yawing moment due to the aerodynamic control force (L5227)	(ft-lb)
	$l_{\delta y}$	Yaw movable control fin center-of-pressure to vehicle center-of-gravity lever arm (L5600)	(ft)
	$N_{\delta y}$	Aerodynamic yaw fin normal force (L5156)	(lb)
	M_{hy}	Torque about the yaw fin hinge axis (L5247)	(ft-lb)
E	I_{YY}	Pitch moment of inertia about vehicle center-of-gravity (L5179)	(ft-lb-sec^2)
	z_e	Thrust gimbal pitch point position in the Z_b axis direction (L5590)	(ft)
	x_{cg}	Instantaneous center-of-gravity body station numbers (L5584)	(ft)
	z_{cg}	Center-of-gravity offset bias distance, positive down (L5586)	(dbi)
	θ_b	Achieved missile Euler angle pitch attitude (L5710)	(deg)

Printline	Symbol	Definition	Units
E	Q_b	Instantaneous vehicle angular pitch velocity. Pitch up is positive (L5707)	(deg/sec)
	$\dot{Q}_b$	Instantaneous vehicle angular pitch acceleration. Pitch up positive (L5757)	(deg/sec^2)

Printline	Symbol	Definition	Units
EA	I_{ZZ}	Yaw moment of inertia about vehicle center-of-gravity (L5183)	(ft-lb-sec^2)
	y_e	Thrust gimbal yaw point eccentricity position in the Y_b axis direction (L5589)	(ft)
	y_{cg}	Center-of-gravity offset bias distance positive in the Z_b direction (L5585)	(ft)
	Ψ_b	Achieved missile Euler angle yaw attitude (L5711)	(deg)
	R_b	Instantaneous vehicle angular yaw velocity. Yaw right is positive (L5708)	(deg/sec)
	$\dot{R}_b$	Instantaneous vehicle angular yaw acceleration. Yaw right positive (L5758)	(deg/sec^2)
EB	I_{XX}	Roll moment of inertia about vehicle center-of-gravity (L5175)	(ft-lb-sec^2)
	Φ_b	Achieved missile Euler angle roll attitude (L5712)	(deg)
	$\dot{\Phi}_b$	Achieved vehicle Euler angle roll rate (L5762)	(deg/sec)
	P_b	Instantaneous vehicle angular roll velocity, roll clockwise is positive (L5709)	(deg/sec)
	$\dot{P}_b$	Instantaneous vehicle angular roll acceleration, roll clockwise positive (L5759)	(deg/sec^2)
F	δ_{Pc}	Pitch plane thrust deflection commands (L5339)	(deg)
	δ_p	Pitch thrust deflection angle. Positive up (L5716)	(deg)
	$\dot{\delta}_p$	Pitch thrust deflection angular rate positive up (L5713)	(deg/sec)
	$\ddot{\delta}_p$	Pitch thrust deflection angular acceleration angle positive up (L5763)	(deg/sec^2)
	F_z	Components of total vehicle thrust parallel to the coordinate axes of the b system (L5143)	(lb)
	K_{DP}	Instantaneous control system pitch attitude error gain (L5461)	(dim)

Printline	Symbol	Definition	Units
F	K_{RP}	Instantaneous control system pitch rate gain (L5467)	(sec)
FA	δ_{Yc}	Yaw plane thrust deflection commands (L5340)	(deg)
	δ_Y	Yaw thrust deflection angle, positive left (L5717)	(deg)
	$\dot{\delta}_Y$	Yaw thrust deflection angular rate, positive left (L5714)	(deg/sec)
	$\ddot{\delta}_Y$	Yaw thrust deflection angular acceleration angle positive left	(deg/sec^2)
	F_y	Components of total vehicle thrust parallel to the coordinate axes of the b system (L5142)	(lb)
	K_{DY}	Instantaneous control system yaw attitude error gain (L5462)	(dim)
	K_{RY}	Instantaneous control system yaw rate gain (L5468)	(sec)
FB	$\bar{\delta}_P$	Modified pitch thrust deflection angle to include limit cycle and misalignment angle (L5342)	(deg)
	I_P	Pitch control thrust impulse from stage initiation to the time being printed (L5739)	(lb-sec)
	$I_{\dot{\delta}P}$	Sum of pitch angular thrust vectoring velocities from stage initiation to the time being printed (L5741)	(deg)
	M_{FOQ}	Thrust offset pitching moment (L5214)	(ft-lb)
	$\Delta\theta_b$	Vehicle pitch attitude error angle (L5344)	(deg)
	M_{TDQ}	Movable nozzle tail-wag-dog moment about vehicle center-of-gravity in pitch (L5217)	(ft-lb)
	F_{TDz}	Movable nozzle tail-wag-dog force in pitch, positive down (L5148)	(lb)
FC	$\bar{\delta}_Y$	Modified yaw thrust deflection angle to include limit cycle and misalignment angles (L5343)	(deg)

Printline	Symbol	Definition	Units
FC	I_Y	Yaw control thrust impulse from stage initiation to the time being printed (L5740)	(lb-sec)
	$I_{\dot{\delta}Y}$	Sum of yaw angular thrust vectoring velocities from stage initiation to the time being printed (L5742)	(deg)
	M_{FOR}	Thrust offset yawing moment (L5215)	(ft-lb)
	$\Delta\psi_b$	Vehicle yaw attitude error angle (L5345)	(deg)
	M_{TDR}	Movable nozzle tail-wag-dog moment about vehicle center-of-gravity in yaw (L5218)	(ft-lb)
	F_{TDy}	Movable nozzle tail-wag-dog force in yaw, positive to the right (L5147)	(lb)
FD	F_c	Instantaneous complementary thrust (L5127)	(lb)
	I_R	Auxiliary roll control system delivered total impulse (L5745)	(lb-sec)
	F_D	Instantaneous roll control system phase plane signal (L5449)	(deg)
	$\Delta\phi_b$	Vehicle roll attitude error angle (L5348)	(deg)
	F_R	Instantaneous roll control thrust. Positive is the vehicle is intended to rotate clockwise as seen from the rear of the vehicle. (L5714)	(lb)
	$\dot{F}_R$	Time rate change of roll control thrust (L5769)	(lb/sec)
	$\dot{W}_R$	Roll control system mass flow rate (L5770)	(lb/sec)
G	t_T	Time from target maneuvering initiation (L5010)	(sec)
	S_T	Target down range (L5731)	(ft)
	h_T	Target altitude (L5730)	(ft)
	V_T	Target tangential velocity (L5725)	(ft/sec)
	γ_T	Target pitch flight path angle (L5728)	(deg)

Card							
	t_{MI}	S_{MI}	h_{MI}	R_{MI}	σ_{MI}	ϵ_{MI}	
GB	XXXX.XXXX	XXXXXXXXX.	XXXXXXXX.	XXXXXXXX.	0XXX.XXXX	0XXX.XXXX	
	S_{CMI}	ϵ^*_{MI}	τ_{MI}	δ_{MI}			
GC	XXXXXXXX.	0XXX.XXX	0XXX.XXXX	0XXX.XXXX			
	ϵ_{MT}	$\dot{\epsilon}_{MT}$	$\dot{R}_{MT}$	R_{MT}	σ_{MT}	$\dot{\sigma}_{MT}$	
GD	0XXX.XXXX	0XXXX.XXXX	0XXXX.XX	XXXXXXXX.	0XXX.XXXX	0XXXX.XXXXX	
	δ_{MT}	$\dot{\delta}_{MT}$	λ_{MT}	$\dot{\lambda}_{MT}$			
GE	0XXX.XXXX	0XXXX.XXXX	0XXX.XXXX	0XXXX.XXXXX			
IE	0X.XXXXXXXE0XX						
	c	h_p	h_a	i	t_a	$\Phi_a a_4$	P
J	XXX.XXXXX	XXXX.XXXX	XXXXX.XXX	XXX.XXXXX	XXXXXX.XX	XXXX.XXXX	XXXX.XXXX
	t_f	S_f	μ_f	ρ_f	V_{If}	γ_{1If}	γ_{2If}
JA	0XXXX.XXX	XXXXX.XXX	0XXX.XXXX	0XX.XXXXX	XXXXXX.XX	0XX.XXXXX	XXX.XXXX
	t_E	S_E	V_{aE}	γ_{1E}	V_{1E}	γ_{1IE}	γ_{2IE}
JB	0XXXX.XXX	XXXXX.XXX	0XXXXX.XX	0XX.XXXXX	0XXXXX.XX	0XX.XXXXX	XXX.XXXX
	S_a	γ_{2Ia}	μ_a	ρ_a	V_{Ia}		
JC	0XXXXX.XX	XXX.XXXXX	0XXX.XXXX	0XXX.XXXX	XXXXX.XX		
	X_{ee}	$\dot{X}_{ee}$	$\ddot{X}_{ee}$	Z_{ee}	$\dot{Z}_{ee}$	$\ddot{Z}_{ee}$	
K	0XXXXXXXX.	0XXXXX.XX	0XXXX.XXX	0XXXXXXXX.	0XXXXX.XX	0XXXX.XXX	
	Y_{ee}	$\dot{Y}_{ee}$	$\ddot{Y}_{ee}$	Y_{gg}	$\dot{Y}_{gg}$	$\ddot{Y}_{gg}$	
KA	0XXXXXXXX.	0XXXXX.XX	0XXXX.XXX	0XXXXXXXX.	0XXXXX.XX	0XXXX.XXX	
	X_{gg}	$\dot{X}_{gg}$	$\ddot{X}_{gg}$	Z_{gg}	$\dot{Z}_{gg}$	$\ddot{Z}_{gg}$	
KB	0XXXXXXXX.	0XXXXX.XX	0XXXX.XXX	0XXXXXXXX.	0XXXXX.XX	0XXXX.XXX	
	L_F	L_D	L_g	L_v	ΔV	E/M	
N	XXXXXX.XX	XXXXXX.XX	XXXXXX.XX	0XXXXXX.XX	XXXXXX.XX	XXXXXXX.	
	I	I_v	H_e				
O	0X.XXXXXXXE0XX	0X.XXXXXXXE0XX	0X.XXXXXXXE0XX				
	K^*_{FM}	K^*_{FC}	I_{vT}	I_{vM}	I_{vC}		
P	0X.XXXXXXE0XX	0X.XXXXXXE0X	0X.XXXXXXE0XX	0X.XXXXXXE0XX	0X.XXXXXXE0XX		
	I_{FM}	I_{FC}	$\hat{I}_{vT}$	$\hat{I}_{vM}$	$\hat{I}_{vC}$		
PA	0X.XXXXXXE0XX	0X.XXXXXXE0XX	0X.XXXXXXE0XX	0X.XXXXXXE0XX	0X.XXXXXXE0XX		
	I_{spM}	I_{spC}	I^*_{vT}	I^*_{vM}	I^*_{vC}		
PB	0XXXX.XXXXX	0XXXX.XXXXX	0X.XXXXXXE0XX	0X.XXXXXXE0XX	0X.XXXXXXE0XX		

Printline	Symbol	Definition	Units
G	a_{TT}	Target tangential acceleration (L5444)	(g's)
	a_{TN}	Target normal to its velocity vector acceleration (L5445)	(g's)
GA	S_{TC}	Target cross range (L5732)	(ft)
	γ_M	Relative azimuthal velocity vector angle in missile-target coordinates (L5336)	(deg)
	$\dot{\gamma}_M$	Relative azimuthal velocity vector angular rate in missile-target coordinates (L5337)	(deg)
	ζ_T	Target azimuthal flight path angle (L5729)	(deg)
	a_{TC}	Target transverse acceleration (L5446)	(g's)
GB	t_{MI}	Estimated time to intercept (L5439)	(ft)
	S_{MI}	Estimated earth surface down range at target intercept (L5441)	(ft)
	h_{MI}	Estimated altitude at target intercept (L5442)	(ft)
	R_{MI}	Estimated range to target intercept (L5400)	(ft)
	Γ_{MI}	Local flight path angle to estimated target, intercept (L5373)	(deg)
	ϵ_{MI}	Pitch flight path error to estimated intercept (L5355)	(deg)
GC	S_{CMI}	Estimated earth surface cross range at target intercept (L5443)	(ft)
	$\epsilon*_{MI}$	Angle between estimated intercept velocity vector and missile velocity vector (L)	(deg)
	T_{MI}	Azimuthal angle to target intercept (L5374)	(deg)
	δ_{MI}	Azimuth flight path error to intercept. Used in type 10 flight (L5338)	(deg)
GD	ϵ_{MT}	Seeker pitch look angle (L5356)	(deg)
	$\dot{\epsilon}_{MT}$	Seeker pitch look angular rate (L5357)	(deg/sec)

Printline	Symbol	Definition	Units
GD	$\dot{R}_{MT}$	Time rate change of missile to target distance (L5438)	(ft/sec)
	R_{MT}	Missile to target range distance (L5437)	(ft)
	σ_{MT}	Angle of missile to target line and local horizontal (L5371)	(deg)
	$\dot{\sigma}_{MT}$	Angular rate of missile to target line and local horizontal (L5372)	(deg/sec)
GE	δ_{MT}	Seeker yaw look angle (L5351)	(deg)
	$\dot{\delta}_{MT}$	Seeker yaw look angular rate (L5352)	(deg/sec)
	λ_{MT}	Angle of missile to target line projection on horizontal and firing azimuth (L5360)	(deg)
	$\dot{\lambda}_{MT}$	Angular rate of missile to target line projection or horizontal and firing azimuth (L5361)	(deg/sec)
IE	l_{lr}	Missile travel distance on the rail launcher used in ground launch type of flight (Ty=6) (L5113)	(ft)
J	e	Eccentricity of the missile path during the glide phase (L5112)	(dim)
	h_p	Perigee altitude of the missile during the glide phase (L5032)	(nm)
	h_a	Apogee altitude of the missile during the glide phase (L5031)	(nm)
	i	Orbital inclination angle (L5111)	(deg)
	t_a	Total flight time to the glide phase apogee altitude (L5012)	(sec)
	$\Phi_{a a_4}$	Glide range angle to the apogee vertical (L5114)	(deg)
	P	Glide phase orbital period (L5014)	(min)
JA	t_f	Total flight time to the termination of glide phase (L5014)	(sec)
	S_f	Total missile ground range at the termination of the glide phase (L5024)	(nm)

Printline	Symbol	Definition	Units
JA	μ_f	Missile impact or intercept longitude if powered flight and the atmosphere end at the time being printed (L5366)	(deg)
	ρ_f	Missile impact or intercept latitude if powered flight and the atmosphere end at the time being printed (L5370)	(deg)
	V_{If}	Missile inertial velocity at apogee and impact of intercept, respectively, if powered flight and the atmosphere end at the time being printed (L5042)	(ft/sec)
	γ_{1If}	Impact or intercept inertial pitch flight path angle, if powered flight and the atmosphere end at the time being printed (L5332)	(deg)
	γ_{2If}	Impact or intercept inertial yaw flight path azimuthal angle, if powered flight and the atmosphere end at the time being printed (L5333)	(deg)
JB	t_E	Total flight time to atmospheric entry (L5013)	(sec)
	S_E	Total missile ground range to atmospheric entry (L5023)	(nm)
	V_{aE}	Velocity with respect to the ambient air at entry (L5058)	(ft/sec)
	γ_{1E}	Pitch flight path angle with respect to the ambient air at entry conditions (L5327)	(deg)
	V_{IE}	Inertial velocity at entry conditions (L5059)	(ft/sec)
	γ_{1IE}	Entry conditions inertial pitch flight path angles, if powered flight and the atmosphere end at the time being printed (L5328)	(deg)
	γ_{2IE}	Entry conditions inertial yaw flight path azimuth angle, if powered flight and the atmosphere end at the time being printed (L5329)	(deg)
JC	S_a	Total missile ground range at flight apogee (L5022)	(nm)

Printline	Symbol	Definition	Units
JC	γ_{2Ia}	Inertial azimuth flight path angle at apogee (L5326)	(deg)
	μ_a	Vehicle apogee long' ude if powered flight and the atmosphere end at the time being printed (L5365)	(deg)
	ρ_a	Vehicle apogee latitude if powered flight and the atmosphere end at the time being printed (L5369)	(deg)
	V_{Ia}	Missile inertial velocity at apogee if powered flight ends at the time being printed (L5041)	(ft/sec)
K	X_{ee}	Instantaneous component of vehicle position north of launcher (L5704)	(ft)
	$\dot{X}_{ee}$	Instantaneous components of vehicle velocity, north of the launcher (L5701)	(ft/sec)
	$\ddot{X}_{ee}$	Instantaneous northerly component of vehicle acceleration at launcher (L5751)	(ft/sec^2)
	Z_{ee}	Instantaneous component of vehicle position negative up from sea level launcher latitude (L5706)	(ft)
	$\dot{Z}_{ee}$	Instantaneous component of vehicle velocity negative up from sea level launcher latitude (L5703)	(ft/sec)
	$\ddot{Z}_{ee}$	Instantaneous downward component of vehicle acceleration at launcher (L5753)	(ft/sec^2)
KA	Y_{ee}	Instantaneous component of vehicle position east of launcher (L5705)	(ft)
	$\dot{Y}_{ee}$	Instantaneous components of vehicle velocity, east of the launcher (L5703)	(ft/sec)
	$\ddot{Y}_{ee}$	Instantaneous easternly component of vehicle acceleration at launcher (L5752)	(ft/sec^2)
	Y_{gg}	Instantaneous component of vehicle position in the generalized coordinates cross range from launcher (L5523)	(ft)
	$\dot{Y}_{gg}$	Instantaneous component of vehicle velocity in the generalized coordinates crosswise from launcher (L5526)	(ft/sec)

Printline	Symbol	Definition	Units
KA	$\ddot{Y}_{gg}$	Instantaneous component of vehicle acceleration in the generalized coordinates crosswise from launcher (L5529)	(ft/sec^2)
KB	X_{gg}	Instantaneous component of vehicle position in the generalized coordinates down range from launcher (L5522)	(ft)
	$\dot{X}_{gg}$	Instantaneous component of vehicle velocity in the generalized coordinates down range from launcher (L5525)	(ft/sec)
	$\ddot{X}_{gg}$	Instantaneous component of vehicle acceleration in the generalized coordinates down range from launcher (L5528)	(ft/sec^2)
	Z_{gg}	Instantaneous component of vehicle positive vertical from launcher (L5524)	(ft)
	$\dot{Z}_{gg}$	Instantaneous component of vehicle velocity in the generalized coordinates vertical from launcher (L5527)	(ft/sec)
	$\ddot{Z}_{gg}$	Instantaneous component of vehicle acceleration in the generalized coordinates vertical from launcher (L5530)	(ft/sec^2)
N	L_F	Output total velocity loss due to back pressure from stage initiation to the time being printed (L5743)	(ft/sec)
	L_D	Drag velocity loss from stage ignition (L5746)	(ft/sec)
	L_g	Gravity losses, from trajectory initiation to the time being printed (L5748)	(ft/sec)
	L_v	Output ideal velocity vectoring losses (L5118)	(ft/sec)
	Δv	Ideal missile velocity resulting from achieved thrust (L5744)	(ft/sec)
	E/m	Total missile energy per unit mass during the glide phase. Potential energy at the launcher is taken as zero (L5109)	(ft^2-sec^2)
O	I	Total missile impulse measured from stage initiation to the time being printed (L5737)	(lb-sec)

Printline	Symbol	Definition	Units
O	I_V	Total missile vacuum impulse, measured from stage initiation to the time being printed (L5738)	(lb-sec)
	H_e	Heating parameter. Integral of qv from stage initiation to the time being printed (L5747)	(lb/ft)
P	K^*_{FM}	Calculated main table thrust multiplier for K-th stage	(dim)
	K^*_{FC}	Calculated complementary table thrust multiplier for K-th stage	(dim)
	I_{vT}	Calculated input vacuum corrected main and complementary impulse corrected for K-th stage	(lb-sec)
	I_{vM}	Calculated input vacuum corrected main table time adjusted thrust integral for K-th stage	(lb-sec)
	I_{vC}	Calculated input vacuum corrected complementary table time adjusted thrust integral for K-th stage	(lb-sec)
PA	I_{FM}	Calculated main table nozzle back pressure impulse for K-th stage	(lb-sec)
	I_{FC}	Calculated complementary table nozzle back pressure impulse for K-th stage	(lb-sec)
	$\hat{I}_{vT}$	Calculated input main and complementary impulse corrected to vacuum condition for K-th stage	(lb-sec)
	$\hat{I}_{vM}$	Calculated main table input total impulse adjusted to vacuum conditions for K-th stage	(lb-sec)
	$\hat{I}_{vC}$	Calculated complementary table input total impulse adjusted to vacuum condition for K-th stage	(lb-sec)
PB	I_{spM}	Input main specific impulse used to compute vehicle weight flow. If zero, weight flow is determined from the input weight flow. Also output in the TVC duty cycle (Lk010)	(sec)

Printline	Symbol	Definition	Units
PB	I_{spC}	Input complementary specific impulse used to compute vehicle weight f' . If zero, weight flow is determine. ~om input weight flow (Lk103)	(sec)
	I^*_{vT}	Calculated main and complementary vacuum adjusted thrust integral for K-th stage	(lb-sec)
	I^*_{vM}	Calculated main table vacuum adjusted thrust integral for K-th stage	(lb-sec)
	I^*_{vC}	Calculated complementary table vacuum adjusted thrust integral for K-th stage	(lb-sec)

OUTPUT PRINT FORMAT II

DUTY CYCLE PRINT

	$\bar{I}$	$\bar{I}_v$	x_e	x_{nf}	δ_{me}	
	I-DEL	I-VAC	X-E	X-NF	D-DESIGN	
WA	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX	OXXXX.XXXX	OXXXX.XXXX	OXX.XXXX	
	I_{spM}	$h'_{q\alpha}$	$P_{q\alpha}$	ω_c	$\ddot{\delta}_S$	$\bar{\delta}_S$
	ISPVACM	H-Q ALPHA	P-Q ALPHA	CONT FREQ	SLEW	D-SLEW
WB	OXXXX.XXXX	OXXXXXXX	OXXXX.XXXX	OXXXX.XXXX	OXXX.XXXX	OXX.XXXX
	I_P	$\bar{I}_{\dot{\delta}p}$	$t_{\eta P}$	η_P	$\dot{\delta}_{Pmax}$	$\bar{\delta}_{pmax}$
	I-P	I-DDOTP	T-NP	ETA-P	DDOT-PMAX	D-PMAX
WC	OX.XXXXXXXXEOXX	OXXXXX.XX	OXXXX.XXXX	OX.XXXXXX	OXXXX.XXXX	OXX.XXXX
	$\bar{I}_y$	$\bar{I}_{\dot{\delta}y}$	$t_{\eta y}$	η_y	$\dot{\delta}_{ymax}$	$\bar{\delta}_{ymax}$
	I-Y	I-DDOTP	T-NY	ETA-Y	DDOT-YMAX	D-YMAX
WD	OX.XXXXXXXXEOXX	OXXXXX.XX	OXXXX.XXXX	OX.XXXXXX	OXXXX.XXXX	OXX.XXXX
	$q\alpha'_{max}$	$q'_{q\alpha}$	$t'_{q\alpha}$	$C_{n\alpha q}$	$M'_{q\alpha}$	$\bar{\delta}_{ave}$
	Q-ALPHA	Q-Q APLHA	T-Q ALPHA	NORM COEF	MACH Q A	D-AVE
WE	OXXXXXXX.XX	OXXXXX.XX	OXXXX.XXXX	OX.XXXXXX	OXX.XXXX	OXX.XXXX

	K_{dc}	D_B	A_{FW1}	t_{Ba}	F_{vave}	W_o
	STG	CASE DIA	VEH VTHR/WT	STG TIME	STG VAC THRUST	STG LIFTOFF WT
WF	X	OXXXX.XXXX	OXXX.XXXXX	OXXXX.XXXX	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX

	R_{PFV}	ϵ_d	$\bar{A}_t$	α'_d	P_{ca}	$C*$
	PC/FMV	EXP RAT	AT	GAMMA	PCA	C-STAR
WG	OX.XXXXXXXXEOXX	OXXXX.XXXX	AXXXXX.XXX	OX.XXXXX	OXXXX.XXX	OXXXXX.XX

	W_{TVC}	W_{exi}	I_{spaug}	P_{cmax}
	WTVC	W-EXJ	ISP-AUG	PC-MAX
WH	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX

	n_m	n_c	n_{dc}	M_{hzmax}	M_{hymax}
	N-M	N-C	N-DC	M-HINGE-P	M-HINGE-Y
WI	XXX	XXX	XXX	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX

	I_{vM}	W_{MO}	K_{tM}
	IVT-MAIN	WGT-MAIN	KT-MAIN
WJ	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX	OX.XXXXXXXXEOXX

	$\mathring{A}_{tmax}$	I_{at}	A_{xmax}
	ADTMAX	IAT	AXMAX
WK	$\pm$0.XXXXXXEDXX	$\pm$0.XXXXXXEDXX	$\pm$XXXXX.XXXX

	F_{max}	P_{cmax}	ϵ_{max}	A_{tmin}	C_{fmax}
	FMAX	PCMAX	EPSMAX	ATMIN	CFMAX
WL	$\pm$XXXXXXXX.XX	$\pm$XXXXX.XXXX	$\pm$XXXX.XXXX	$\pm$XXXXX.XXXX	X.XXXXXX
	F_{min}	P_{cmin}	ϵ_{min}	A_{tmax}	C_{fmin}
	FMIN	PCMIN	EPSMIN	ATMAX	CFMIN
WM	$\pm$XXXXXXXX.XX	$\pm$XXXXX.XXXX	$\pm$XXXX.XXXX	$\pm$XXXXX.XXXX	$\pm$X.XXXXXX

	t_{Bq}	δ_{Pq}	δ_{yq}	F_q	X_{cgq}	$\bar{F}_{vacq}$	$\dot{\bar{W}}_q$
	TIME	D-PITCH	D-YAW	F-JEL	X-CG	F-VAC	W-DOT
WO	XXXX.XXX	OXX.XXXXX	OXX.XXXXX	XXXXXXXX.X	XXXX.XXXXX	XXXXXXXX.X	XXXXXX.XX
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
WO	XXXX.XXX	OXX.XXXXX	OXX.XXXXX	XXXXXXXX.X	XXXX.XXXXX	XXXXXXXX.X	XXXXXX.XX

Printline	Symbol	Definition	Units
WA	$\bar{I}$	Output motor thrust impulse for TVC duty cycle stage	(lb-sec)
	$\bar{I}_v$	Output motor vacuum thrust impulse for TVC duty cycle stage	(lb-sec)
	x_e	Output stage thrust gimbal body station numbers, for the TVC duty cycle (Lk431)	(ft)
	x_{nf}	Input body station of nozzle flange. Used in the TVC design program (L0680)	(ft)
	$\delta_{m?}$	Input maximum vector angle design limit also output in TVC design duty cycle (L0681)	(deg)
WB	I_{spM}	Input main specific impulse used to compute vehicle weight flow. If zero, weight flow is determined from the input weight flow. Also output in the TVC duty cycle (Lk010)	(sec)
	$h_{q'\alpha}$	TVC duty cycle stage altitude at maximum $q\alpha'$	(ft)
	$P_{q'\alpha}$	TVC duty cycle stage atmospheric pressure at maximum $q\alpha'$	(lb/ft^2)
	ω_c	Input stage pitch control systems forcing frequency for the thrust vector deflection second-order transfer function (Lk437)	(rad/sec)
	$\bar{\dot{\delta}}_S$	Output control system design slew rate for TVC design stage	(deg/sec)
	$\bar{\delta}_S$	Output pitch slew angle for TVC design stage	(deg)
WC	I_P	Pitch control thrust impulse from stage initiation to the time being printed (L5739)	(lb-sec)
	$\bar{I}_{\dot{\delta}_P}$	Sum of pitch angular thrust vectoring velocities from stage initiation to the time being printed corrected for dither (L5116)	(deg)
	$t_{\eta P}$	Output stage time at which maximum magnitude pitch thrust vector deflection angle occurs during the TVC design stage (δ_{Pmax})	(sec)

Printline	Symbol	Definition	Units
WC	η_P	Ratio of the delivered thrust [F] to vacuum thrust [F_v] at maximum magnitude pitch and yaw TVC deflection angle [δ_{Pmax}]	(dim)
	$\dot{\delta}_{Pmax}$	Output maximum pitch thrust vector deflection angular rate, respectively for the TVC design stage	(deg/sec)
	$\bar{\delta}_{Pmax}$	Output maximum magnitude pitch thrust vector deflection angles respectively, per control motor for the TVC design stage	(deg)
WD	$\bar{I}_Y$	Input moment of inertia mulitplier (Lk475)	(dbi)
	$\bar{I}_{\dot{\delta}y}$	Sum of yaw angular thrust vectoring velocities from stage initiation to the time being printed corrected for dither (L5117)	(deg)
	$t_{\eta y}$	Stage time at which maximum magnitude yaw thrust vector deflection angle occurs during the TVC design stage (δ_{Ymax})	(sec)
	η'_y	Ratio of the delivered thrust (F) to vacuum thrust (F_v) at maximum magnitude yaw TVC deflection angle (δ_{Ymax})	(dim)
	$\dot{\delta}_{Ymax}$	Maximum yaw thrust vector deflection angular rate, for the TVC design stage	(deg/sec)
	$\bar{\delta}_{Ymax}$	Maximum magnitude yaw thrust vector deflection angle, per control motor for the TVC design stage	(deg)
WE	$q\alpha'_{max}$	Output product of the maximum absolute value of the dynamic pressure-angle of attack for the TVC design stage	(lb-deg/ft^2)
	$q_q^{\alpha'}$	Output dynamic pressure at maximum $q\alpha'$ during the TVC duty cycle stage	(lb/ft)
	$t_{q\alpha'}$	Output TVC duty cycle stage time at maximum $q\alpha'$	(sec)

Printline	Symbol	Definition	Units
WE	$\dot{C}_{n\alpha_q}$	Output aerodynamic normal force coefficient at maximum $q\alpha'$ during the TVC duty cycle stage	(1/deg)
	$\dot{M}_{q\alpha}$	Output Mach number at maximum $q\alpha'$ during the TVC duty cycle stage	(dim)
	$\bar{\delta}_{ave}$	Output average TVC deflection angle per control motor for the TVC design stage	(deg)
WF	K_{dc}	Output stage number of TVC duty cycle stage (L0671)	(dim)
	D_B	Output TVC duty cycle stage case diameter from axial force reference area	(in)
	A_{FWI}	Stage I vacuum thrust to liftoff weight used in the vehicle characteristics pertinent to roll requirement (L0675)	(g's)
	t_{Ba}	Output TVC duty cycle stage time	(sec)
	F_{vave}	Output TVC duty cycle stage average vacuum thrust	(lb)
	W_o	Output TVC duty cycle stage liftoff weight used in the roll control requirements	(lb)
WG	R_{PFV}	Output ratio of motor chamber pressure to vacuum thrust of the main thrust table of the TVC design stage	$(1/in^2)$
	ϵ_d	Input and output nozzle expansion ratio used in the separated flow nozzle thrust equations (Lk013)	(dim)
	$\bar{A}_t$	Output nozzle throat area for the main motor of the TVC design stage	(in^2)
	$\dot{\alpha}'_d$	Input nozzle half angle used in the separated flow nozzle thrust equation (Lk016)	(deg)
	P_{ca}	Output action time average motor chamber pressure for the TVC design duty cycle stage	(lb/in^2)
	C^*	Output rocket motor propellant characteristic velocity for the TVC design duty cycle stage	(ft/sec)

Printline	Symbol	Definition	Units
WH	W_{TVC}	Input and output estimated TVC system fixed weight. Used in TVC design stage for the refly option (L0677)	(lb)
	W_{exi}	Input estimated weight of the TVC system expend weight during the TVC design stage during the original vehicle flight (L0678)	(lb)
	I_{spaug}	Input and output estimated TVC system caused specific impulse augmentation (positive) or degradation (negative). Used in trajectory TVC design program refly (L0679)	(sec)
	P_{cmax}	Output maximum main motor chamber pressure used in separated flow equations	(lb/ft^2)
WI	n_m	Output internally calculated number of motors in the stage cluster (Lk380)	(dim)
	n_c	Output internally calculated number of control nozzles for the cluster motor logic (Lk381)	(dim)
	n_{dc}	Output of number TVC duty cycle t_B data points	(dim)
	M_{hzmax}	Output maximum of the absolute value pitch fin hinge torque for the TVC design stage	(ft-lb)
	M_{hymax}	Output maximum of the absolute value yaw fin hinge torque for the TVC design stage	(ft-lb)
WJ	I_{vM}	Calculated input vacuum corrected main table time adjusted thrust integral for k-th stage	(lb-sec)
	W_{MO}	Input initial main weight for the k-th stage (Lk006)	(lb)
	K_{tM}	Output for the TVC duty cycle stage, the main switching time multiplier	(dim)
WK	$\dot{A}_{tmax}$	Pintle system required throat area rate (L7060)	(in^2/sec)
	I_{At}	Integral of the absolute value of the pintle throat area rate (L7061)	(in)

Printline	Symbol	Definition	Units
WK	A_{xmax}	Motor extinguishment throat area (L7072)	(in^2/sec)
WL	F_{max}	Pintle motor maximum vacuum thrust (L7062)	(lb)
	P_{cmax}	Pintle motor chamber pressure at maximum vacuum thrust (L7063)	(lb/in^2)
	ϵ_{max}	Pintle motor expansion ratio at maximum vacuum thrust (L7064)	(dim)
	A_{tmin}	Pintle motor throat area at maximum vacuum thrust (L7065)	(in^2)
	C_{fmax}	Pintle motor vacuum thrust coefficient at maximum vacuum thrust (L7066)	(dim)
WM	F_{min}	Pintle motor minimum vacuum thrust (L7067)	(lb)
	P_{cmin}	Pintle motor chamber pressure at minimum vacuum thrust (L7068)	(lb/in^2)
	ϵ_{min}	Pintle motor expansion ratio at minimum vacuum thrust (L7069)	(dim)
	A_{tmax}	Pintle motor throat area at minimum vacuum thrust (L7070)	(in^2)
	C_{fmin}	Pintle motor vacuum thrust coefficient at minimum vacuum thrust (L7071)	(dim)
WO	t_{Bq}	Output stage time at which TVC duty points occur	(sec)
	δ_{Pq}	Pitch thrust deflection angle at t_{Bj}	(deg)
	δ_{Yq}	Output modified yaw thrust deflection angle at t_{Bq} for TVC design stage	(deg)
	F_q	Delivered motor thrust (F) at t_{Bq} during TVC design stage	(lb)
	X_{cgq}	Output vehicle center-of-gravity at t_{Bq}; the TVC duty cycle point	(ft)
	$\bar{F}_{vacq}$	Output vacuum motor thrust ($\bar{F}_{vac}$) during the TVC design stage at t_{Bq}	(lb)

Printline	Symbol	Definition	Units
WO	$\dot{W}_q$	Output motor weight flow ($\dot{W}$) at t_{Bq} the TVC duty cycle point	(lb/sec)

APPENDIX B

TRAJECTORY INPUT CODES FOR PARAMETER FLAGS

This appendix delineates the logic control flags used in the trajectory routine. These codes control the kind and sophistication of the desired trajectory simulation.

1. MODE CONTROL TABLE FLAGS

The mode table controls the degree of sophistication that is obtained in the simulation of missile flight. Options such as rigid body with and without thrust vector control are controlled by the mode table. The desired option or mode is determined by the type of mode input My in the mode control table row, i.e. L600, L603, ..., L627.

Flight Simulation Mode

M_y	
4	Point Mass 3 Degrees of Freedom
5	Rigid Body 6 Degrees of Freedom

2. ATTITUDE CONTROL TABLE FLAGS

The desired missile attitude will be computed by one of the many types of flight methods. The type of attitude control desired will be determined by the "type of flight" input Ty in the attitude control table row, i.e. L310, L317, ..., or L394.

Types of Flight

Ty	
1	Commanded Turning Rates
2	Gravity Turn
4	Velocity Steering
6	Rail Launch
7	Constant Altitude
9	Constant Normal Load Factor
10	Intercept Guidance
11	Homing Guidance

3. SWITCHING CODE

Quantities which can be involved as switching functions or in the hunting procedure are assigned a code number. These codes are delineated as P-numbers corresponding to all output parameters. The code number is input in the appropriate space on the load sheet (generally delineated symbolically as σ) and the program determines the parameter which corresponds to the code number. The parameter and not the code input is used in program equations and logic.

The input parameter code is designated by inputting the L-number (delete the "L" of the parameters). These parameters can be used only as independent variables in the hunting procedure.

If the sigma code number is input negatively, the absolute value of the parameter is then utilized in the program equations and logic.

4. THRUST MODULATION CONTROL TABLE FLAGS

The thrust control law type is determined from a sequential inputthrust modulation control type, input Fy in the thrust modulation control table row, i.e. L800, L810, ..., L860.

Fy	Thrust Control Law Mode
1	Specific Velocity-Time Profile
2	Constant Mach Number
3	Proportional-to-Commanded Turning Rate Profile
4	Minimum Velocity During Commanded Turning Rate Profile
5	Constrained Dynamic Pressure
6	Axial Acceleration Proportional to Line-of-Sight Rate

Thrust dynamic mode is input in the thrust modulation control table row, i.e. L803, L813, ..., L863.

If TMC = 0, perfect i.e. $P_c = P_{cc}$

If TMC = 1, solves P_c equation

5. SHAPER FLAG

K_{sh} Input shaper control flag where: if it equals zero, ignore routine (dim)

1. Maximize range,
2. Maximize payload to a given range, or
3. Determine payload to a circular orbit (L0598)

The shaper routine utilizes a generalized attitude control table and sets up the hunting procedure to: 1) maximize range for a given payload, 2) maximize payload to a given range, or 3) isolate the payload weight for a given circular orbit.

6. HUNTING PROCEDURE FLAGS

One by One

P_1 Input flag to specify hunt procedure if nonzero (P1) (L0073) (dim)

K_a Input isolation-maximization control function. If zero, isolation is specified and if nonzero, maximization of the dependent variables will occur used in hunting procedure (P1) (L0076) (dim)

K_a = 0, isolation

1, maximize

P1 < 0, minimize

K_S Input stage print control function. A nonzero value is required to print the trajectory at the termination of each stage during the hunting procedure (L0074) (dim)

Multi Variable

P_2 Input flag to specify hunt procedure (P2). If $P_2 = 0$, by-pass hunt procedure 2; $P_2 = 1$, use a linear response; $|P_2| = 2$, use a quadratic response surface where +2 maximizes and -2 minimizes; $|P_2| = 3$, use an incomplete quadratic response surface where +3 maximizes and -3 minimizes. (L0084) (dim)

$P2 > 1$, maximize

$P2 < 1$, minimize

$|P2|$ = liner model, (isolation), 2, quadratic model = 3 incomplete quadratic model

7. STAGE START FLAGS

K'_k Input stage start control function. If 1, 2, 3, or 4, the run starts at the initiation of the first, second, third, or fourth stage, respectively if input zero set equal to 1 (L0003) (dim)

K_{dc} Input and output stage number of TVC duty cycle stage (L0671) (dim)

8. IMPACT CONTROL FLAG

K_γ Input glide phase termination control function. A value of plus 1 will specify impact after apogee, while a minus 1 will specify impact before apogee (L0040) (dim)

9. SPECIAL PRINT FLAGS

PL-DA GB,K,KB, N,O Input flag where nonzero values are required if printlines DA, GB, K, KB, N, O are desired (L0200-209) (dim)

T_{mj} Input maximum print region flag (L0260, 262), etc. (dim)

T_{mj} ~ maximum/minimum control flag

> 0 maximum

< 0 minimum

$|T_m|$ = 0 each stage

= 1, 2, 3, or 4 delineated stage

= 5 all stages

K_{TPF}	Input titled print flag, if nonzero (L0683)	(dim)

A format of printline A, B, C, and D is printed at the top of each page.

10. WEIGHT CARRYOVER FLAGS

K_{NOk}	Input complementary thrust-weight table weight carryover flag for the k-th stage. If K_{Ok} and K_{NOk} are nonzero, separation has occurred with regards to the complementary weight. If K_{Ok} is nonzero and K_{NOk} is zero, the total vehicle weight at the termination of the k-1 stage is used as the initial weight of the k-th stage (Lk107)	(dim)
K_{Ok}	Input main thrust-weight table weight carryover flag for the k-th stage. If zero, separation has occurred with regards to the main and complementary weights. If nonzero, the main weight at the termination of the k-1 stage is used as the initial main weight of the k-th stage (Lk012)	(dim)

11. AUTO PILOT FLAGS

K_δ	Input thrust control flag. If zero, control thrust is determined from instantaneous vehicle thrust. If 1, the control thrust is obtained from the instantaneous main stage thrust, if 2 control thrust is nonexistent (Lk434)	(dim)

f_{Gik} Input attitude control system gain control flag. If equal to zero, input gains are utilized; if not equal to zero, the automatic gains, calculated from vehicle control response frequency and damping ratio, i.e. ω_v and ζ_v. are utilized for the j-th control zone, i = 1,2, or 3; and k-th stage, k = 1,2,3, or 4 (Lk456, 465, etc). (dim)

12. NOZZLE BASE DRAG FLAG

K_{BD} Input flag which stipulates that the main nozzle exit area will be used in the base drag calculations when splitting main and complementary tables to allow for up to 47 thrust time points. (Lk108) (dim)

13. ROLL CONTROL FLAG

K_{rc} Input roll control system flag (Lk405) (dim)

If K_{rc} = 1 Auxiliary roll thrusters are used

If K_{rc} = 2 Aerodynamic control fins are used

APPENDIX C

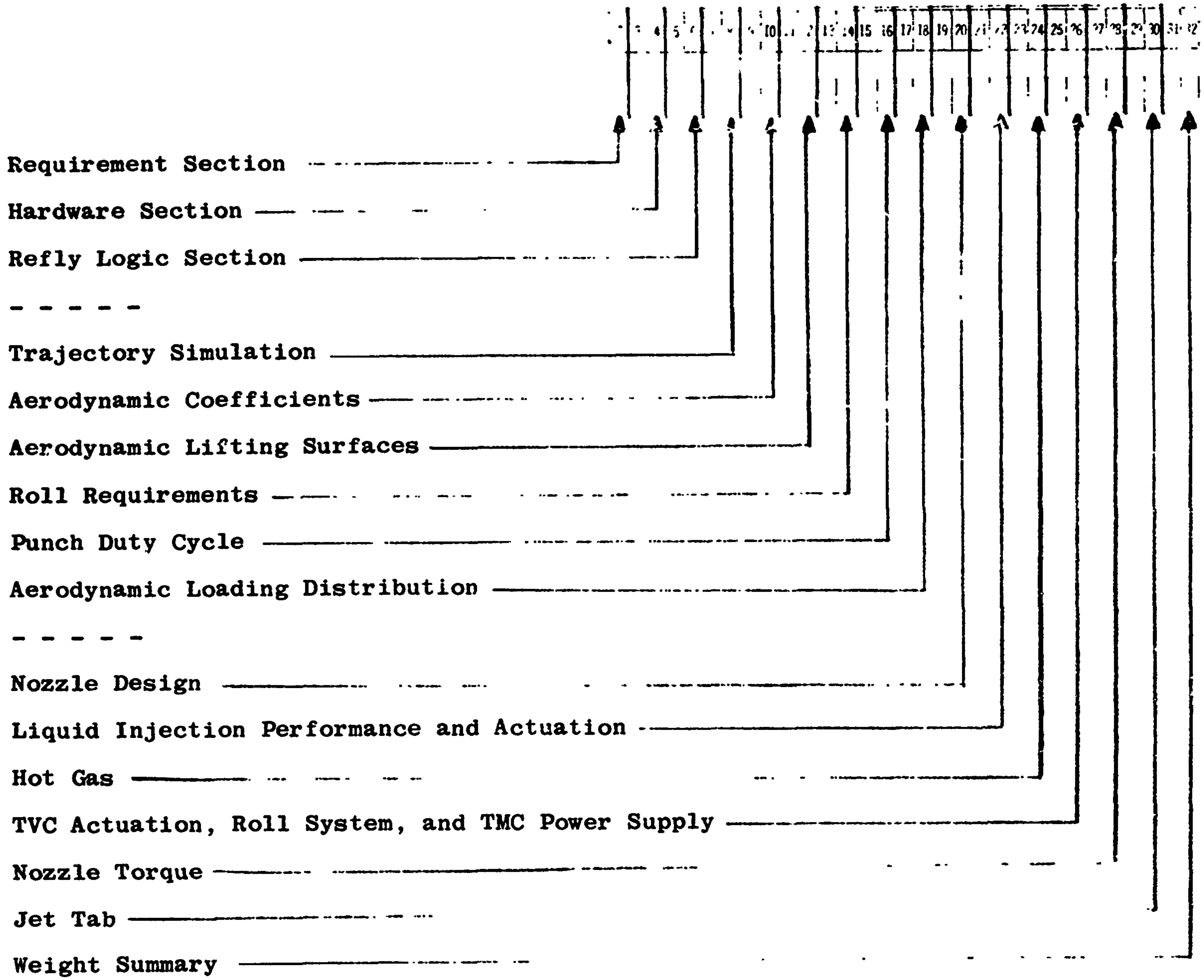
FINAL PROGRAM REVIEW BRIEFING CHARTS

The briefing charts given at the final program review at RPL in June 1972 are shown in this appendix. These charts basically show how to prepare input for the Advanced ASC/TMC Preliminary Design Digital Computer Program. Delineated are instructions for the input executive control cards, trajectory operation philosophy, required input as a function of kind of trajectory simulation desired, generated duty cycle, and required hardware input peculiar to the pintle nozzle design.

ADVANCED ASC/TMC PRELIMINARY

DESIGN DIGITAL COMPUTER PROGRAM

EXECUTIVE CONTROL (1ST CARD) FORTRAN INPUT



THREE PHASES

	EXECUTIVE CONTROL CARD COLUMN
1. REQUIREMENT ANALYSIS WHICH ESTABLISHES DESIGN DUTY CYCLE WITH USE OF TRAJECTORY CODE	2 EQUAL 1
2. HARDWARE DESIGN WHICH CALCULATES TVC/TMC SYSTEM COMPONENT SIZES AND WEIGHT FROM DESIGN DUTY CYCLE CALCULATED IN PHASE 1	4 EQUAL 1
3. REFLY INCLUDES NEWLY DESIGNED HARDWARE DATA IN TRAJECTORY ROUTINE TO EVALUATED PERFORMANCE	6 EQUAL 1

DUTY CYCLE

REQUIREMENTS SECTION ESTABLISHES THE FOLLOWING DESIGN DUTY CYCLE DATA

1. PITCH/YAW TVC REQUIREMENTS

   - MAXIMUM TVC ANGLE & ANGULAR INTEGRALS
   - TVC SLEW RATE
   - EXTERNAL AERODYNAMIC CONDITIONS AT NOZZLE
   - TIME HISTORY OF DEFLECTION ANGLES, THRUST, MISSILE CENTER-OF-GRAVITY, & GAS FLOW RATE THROUGH NOZZLE

2. ROLL CONTROL REQUIREMENTS

   - MAXIMUM ROLL TORQUE & TORQUE INTEGRALS

3. AERODYNAMIC CONTROL SURFACE

   - MAXIMUM CONTROL TORQUE & TORQUE INTEGRALS
   - FIN SIZE, WEIGHT, AND CENTER-OF-GRAVITY

4. TMC REQUIREMENTS

   - MAXIMUM & MINIMUM THROAT AREA, THRUST & CHAMBER PRESSURE
   - REQUIRED TIME RATE CHANGE OF THROAT AREA & RATE INTEGRAL
   - EXTINGUISHMENT THROAT AREA & CHAMBER PRESSURE

* TVC DUTY CYCLE DATA IS STORED IN L7000 THROUGH L7899

* EXECUTIVE CONTROL CARD
COLUMN 8 EQUAL 1

TRAJECTORY ANALYSIS METHOD

1. FLY POINT MASS TRAJECTORY WITH USE OF HUNTING PROCEDURE TO SHAPE FLIGHT PATH AND EVALUATE PARAMETERS SUCH AS VELOCITY HISTORY AND STEERING COEFFICIENTS

2. FLY RIGID BODY WITH CONTROLS AND ROLL REQUIREMENTS TO EVALUATE DUTY CYCLE REQUIREMENTS

DATA INPUT ROUTINE
(CTINP)

- VARIABLE FIELD, INDIVIDUALLY ADDRESSED DATA FIELDS
- L FOLLOWED BY ADDRESS IDENTIFIES DATA LOCATION
- SEPARATE NUMERICAL INPUT IS DISTINGUISHED FROM OTHER SIMILAR INPUT BY THE USE OF ITS ASSOCIATED SIGN "+" OR "-" AND/OR A COMMA ","
- BLANK CARD COLUMNS ARE IGNORED, EXCEPT WHEN READING HOLLERITH DATA
- "T" IN COLUMN 1, SIGNALS END OF DATA
- COLUMNS 2 THROUGH 72 OF T-CARD ARE USED FOR TITLE MESSAGE

TRAJECTORY INPUT PARAMETER UNITS

LINEAR	-	FEET
TIME	-	SECONDS
ANGLE	-	DEGREES
WEIGHT	-	POUNDS
FORCE	-	POUNDS
FREQUENCY	-	RADIANS PER SECOND

SWITCHING LOGIC

TO TERMINATE A CONDITION

1. SPECIFY A P-NUMBER (SIGMA CODE)
2. SPECIFY CORRESPONDING VALUE OF THAT PARAMETER (K-VALUE)

EXAMPLE:

TO TERMINATE THE FIRST ATTITUDE CONTROL ZONE AT

$V_e = 170$ ft/sec

Set L211	+	5504		L312	+	170
	(σ_{f1})	(V_e)			(K_{f1})	(170 ft/sec)

TRAJECTORY INPUT/OUTPUT

L-NUMBERS

0 to 999	Non Stage Input
1000 to 1999	Stage I Input
2000 to 2999	Stage II Input
3000 to 3999	Stage III Input
4000 to 4999	Stage IV Input
5000 to 5999	Output Parameter P-Number

TRAJECTORY INPUT

• Non Stage Dependent

1)	*	Initial Conditions	L 0 - L 43
2)		Weight Jettison Table	L 49 - L 72
3)		Hunting Procedure	L 73 - L167
4)	*	Print Time	L168 - L309
5)	*	Attitude Control Table	L310 - L406
6)	o+	Wind Profile	L407 - L499
7)		Shaper	L598 - L599
8)	o+	Mode Control Table	L600 - L629
9)	$	Target Dynamical Condition	L630 - L669
10)	o+	TVC Duty Cycle Criteria	L670 - L699
11)	#	Thrust Modulation Control Table	L800 - L869
12)	#	Specific Velocity Time Profile	L870 - L899

---

* Mandatory all runs

o Mandatory for duty cycle with TVC

+ Mandatory for duty cycle with aerodynamic controls

$ Mandatory for target dependent flight

Mandatory for TMC duty cycle

TRAJECTORY INPUT

• Stage Dependent		k = Stage Number, i.e. 1, 2, 3, or 4
1) *#	Main Thrust-Weight Table	Lk000 - Lk099
2)	Complementary Thrust-Weight Table	Lk100 - Lk184
3) *	Axial Drag Coefficient Table	Lk185 - Lk219
4) *	Body Aerodynamic Normal Force Coefficient Table	Lk220 - Lk297
5) o+	Aerodynamic Damping Coefficient Table	Lk298 - Lk379
6) o+	Pitch/Yaw Control Data	Lk380 - Lk474
7) o+	Center-of-Gravity and Inertia Data	Lk475 - Lk637
8)	Roll Control Data	Lk638 - Lk666
9)	Aerodynamic Rolling Moment Coefficient Table	Lk667 - Lk699
10) +	Aerodynamic Movable Control Fin Table	Lk700 - Lk799

---

* Mandatory all runs

o Mandatory for duty cycle with TVC

\+ Mandatory for duty cycle with aerodynamic controls

$ Mandatory for target dependent flight

\# Mandatory for TMC duty cycle

INITIAL CONDITIONS

Identification

LOCATION Basic Deck Ref Run Run

L 0 + + +

* Basic Deck & Run must be non zero

Initial Position & Velocity

Velocity, V_{eo} Flight Path, γ_{1o} Altitude, h_o Range, S_o

L 1 0 + + + +

Cross Range, S_{co} Azimuthal Flight Path, γ_{2o}

L 4 3

Launcher Orientation

Launch, ψ_i Launch, θ_i Launch, ϕ_i

L 1 4 + + +

Note: ψ_i determines Down Range Azimuthal Direction

Launch Lat, ρ_L Launch Long, μ_L Launcher Alt, h_L

L 1 7 + + +

Payload Weight

Payload, W_{PL}

L 2 0

Initial Missile Attitude and Rates

Desired, θ_{mo} Desired, ψ_{mo} Desired, ϕ_{mo}

L 2 8 + + +

Miss Rat, θ_{bo}, Q_{bo} Miss Rat, R_{bo} Miss Rat, P_{bo}

L 3 1 + + +

* Used on Rigid Body Trajectory Simulation

Achieved, θ_{bo} Achieved, ψ_{bo} Achieved, ϕ_{bo}

L 3 4 + +

* Used on Rigid Body Trajectory Simulation

Generalized Coordinates

Gen Coord, ψ_g Gen Coord, θ_g Gen Coord, ϕ_g

* Used in Velocity Steering $T_y = 4$

Entry Altitude

Entry Altitude, h_e

L 4 2

WEIGHT JETTISON TABLE

L49	+ W_{JT1}	+ σ_{J1}	+ K_{J1}
L52	+ W_{JT2}	+ σ_{J2}	+ K_{J2}
L55	+ W_{JT3}	+ σ_{J3}	+ K_{J3}
L58	+ W_{JT4}	+ σ_{J4}	+ K_{J4}
L61	+ W_{JT5}	+ σ_{J5}	+ K_{J5}
L64	+ W_{JT6}	+ σ_{J6}	+ K_{J6}
L67	+ W_{JT7}	+ σ_{J7}	+ K_{J7}
L70	+ W_{JT8}	+ σ_{J8}	+ K_{J8}

HUNTING PROCEDURE

1 One by One

L 7 3	P1	K_s	n_{t1}	K_a		σ_X	σ_a
L 8 0	Initial X, X_i	X Increment, ΔX	Final a, a_f	a Accuracy, Δa			

* Hunting procedure input calculated by Shaper Routine

K_a = 0, isolation
1, maximize

P1 < 0, minimize

2 Multi Variable

L 8 4	P2	σ_z	z Accuracy, ϵ_z
L 8 9	Des Max, f_D		n_{t2}

P2 > 1, maximize

P2 < 1, minimize

\|P2\| = liner model, (isolation), 2, quadratic model = 3 incomplete quadratic model

	Independent			Dependent			
	σ_{x1}	Initial X, x_{i1}	X Incr, Δx_{i1}	σ_{y1}	Low y, y_{L1}	Upper y, y_{U1}	Constr Err, ϵ_{c1}
L 9 1							
L 1 0 0	σ_{x2}						
L 1 0 9	σ_{x3}						
L 1 1 8	σ_{x4}						
L 1 2 7	σ_{x5}						
L 1 3 6	σ_{x6}						
L 1 4 5	σ_{x7}	x_{i7}	Δx_{i7}	σ_{y7}	y_{L7}	y_{U7}	ϵ_{c7}

Independent Variable Allowable Maximum & Minimum Values (Restraints)

L 1 5 4	x_{U1}	x_{U2}	x_{U3}	x_{U4}	x_{U5}	x_{U6}	x_{U7}
L 1 6 1	x_{L1}	x_{L2}	x_{L3}	x_{L4}	x_{L5}	x_{L6}	x_{L7}

PRINT TIMES

Main Print

Card								
L184	Δt_{p1}	t_{p1}	Δt_{p2}	t_{p2}	Δt_{p3}	t_{p3}	Δt_{p4}	t_{p4}
L192	Δt_{p5}	t_{p5}	Δt_{p6}	t_{p6}	Δt_{p7}	t_{p7}	Δt_{p8}	t_{p8}

Auxiliary Print

Card											
L209	$\sigma P1$	$\sigma P2$	$\sigma P3$	$\sigma P4$	$\sigma P5$	$\sigma P6$	$\sigma P7$	$\sigma P8$	$\sigma P9$	$\sigma P10$	$\sigma P11$
L220	Δt_{p1}	t_{p1}	Δt_{p2}	t_{p2}	Δt_{p3}	t_{p3}	Δt_{p4}	t_{p4}			
L228	Δt_{p5}	t_{p5}	Δt_{p6}	t_{p6}	Δt_{p7}	t_{p7}	Δt_{p8}	t_{p8}			

Max/Min Print

Card										
L260	Tm1	$\sigma m1$	Tm2	$\sigma m2$	Tm3	$\sigma m3$	Tm4	$\sigma m4$	Tm5	$\sigma m5$

T_{mj} ~ maximum/minimum control flag

> 0 maximum

< 0 minimum

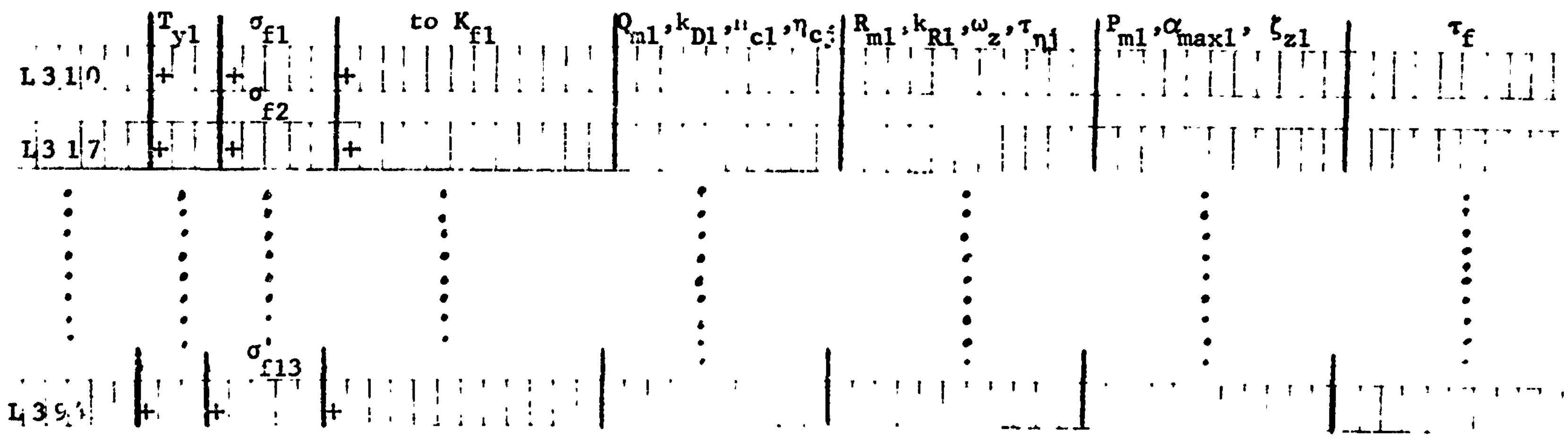
$|T_m|$ = 0 each stage

= 1, 2, 3, or 4 delineated stage

= 5 all stages

ATTITUDE CONTROL TABLE

* Attitude control table input calculated by Shaper Routine



Types of Flight

T_y	
1	Commanded Turning Rates
2	Gravity Turn
4	Velocity Steering
6	Rail Launch
7	Constant Altitude
9	Constant Normal Load Factor
10	Intercept Guidance
11	Homing Guidance

WIND PROFILE

L407 | Alt Mult, K_h | Vel Mult, K_v | Angle Mult, K_ψ

L410 | Altitude, h_1 | Wind Speed, v_{w1} | Wind Angle, ψ_{w1}

L413 | h_2 | v_{w2} | ψ_{w2}

⋮

L497 | h_{30} | v_{w30} | ψ_{w30}

To automatically set up a design wind profile set altitude of maximum wind usually corresponding to altitude of maximum dynamic pressure

L662 | Alt Max Wind h_{mxwd}

SHAPER

Control flag, K_{sh} — Target Range or Oribtal Att, S_{sh}

L | 5 | 9 | 8 | + | ... | + | ...

MAXIMIZE RANGE WITH GIVEN PAYLOAD	$K_{sh} = 1$	TARGET RANGE
MAXIMIZE PAYLOAD TO A GIVEN RANGE	$K_{sh} = 2$	ORBITAL ALTITUDE
DETERMINE PAYLOAD TO A CIRCULAR ORBIT	$K_{sh} = 3$	

Note: This routine automatically sets up Initial Conditions, Hunting Procedure, Main Print Table, and Attitude Control Table for Point Mass Simulation

MODE CONTROL TABLE

	M_y-1	σ_{M1}	to K_{M1}
L 6 0 0	+	+	+
		σ_{M2}	
L 6 0 3	+	+	+
.	.	.	.
.	.	.	.
.	.	.	.
		σ_{M10}	
L 6 2 7	+	+	+

M_y

4 Point Mass 3 Degrees of Freedom

5 Rigid Body 6 Degrees of Freedom

TARGET DYNAMICAL CONDITIONS

L630 + α_{Tto} + K_{Tto} + Velocity, V_{Tto}

L633 + Flight Path A, γ_{To} + Altitude, h_{To} + ζ_{to}

L636 + S_{to} + STCO

TARGET ACCELERATION TABLE

L638 + Time t_{T1} + Tang. Acc, a_{TT1} + Normal Acc, a_{TN1} + Tran. Acc, A_{tci}

L644 + t_{T2} + + +

⋮

L668 + t_{T8} + + +

TVC DUTY CYCLE CRITERIA

TVC Duty Cycle Control

No Duty Pt, Δ_{dc} | Duty Stage, K_{dc}

L670 | + | +

Maximum Wind Shear Zone

Final Wind h, h_{α} | Start Wind h, h_{β}

L672 | + | +

* Values internally calculate
if automatic wind profile used

Nozzle Flange Body Station & Override Max TVC Deflection Angle

Noz Flange, x_{nf} | δ-design, δ_{me}

L680 | + | +

Re-fly

W_{TVC} | W_{exi} | I_{spaug}

L677 | + | + | +

THRUST MODULATION CONTROL TABLE

* Used for TMC Control

Card	F_{y1}	σ_{Fy}	K_{Fy1}	TMCI	C_{fy1}	τ_{y1}	MIN1	q_{max1}	q_{min1}
L800		σ_{Fy1}							
L810		σ_{Fy2}							
L820		σ_{Fy3}							
L830		σ_{Fy4}							
L840		σ_{Fy5}							
L850		σ_{Fy6}							
L860		σ_{Fy7}							

TMC Thrust Dynamic Mode = 0, perfect
= 1 solves $\dot{P}_c$ equation

C_{fy} Thrust System Proportionality System Gain

τ_{fy} Control System Time Constant

MIN Minimum Velocity or Constant Mach Number

F_y	
1	Specific Velocity-Time Profile
2	Constant Mach Number
3	Proportional-to-Commanded Turning Rate Profile
4	Minimum Velocity During Commanded Turning Rate Profile
5	Constrained Dynamic Pressure
6	Axial Acceleration Proportional to Line-of-Sight Rate

SPECIFIC VELOCITY TIME PROFILE

Time, t_{vp1} Velocity, V_{pi}

L 8 7 0 + +

$t_{v\ 2}$

L 8 7 2 + +

.
.
.
.

t_{vp15}

L 8 9 8 + +

* Used only for Fy (TMC Type) = 1

MAIN THRUST-WEIGHT TABLE

Stage Termination Control

L 0 0 0 | σ_S +

L 0 0 3 | k_3 +

Main Stage Weight

L 0 0 6 | Weight, W_{Mo} +

L 0 1 2 | Wt Carry Over, K_0 +

Motor Impulse

L 0 0 4 | Tot Impulse, I'_{vT} + | Main Impulse, I'_{vM} +

L 0 1 0 | Specific I_{mp}, I_{spM} +

Multipliers

L 0 0 7 | Thrust Pert, K'_{FM} + | Weight Pert, K'_{WM} + | Time Pert, K'_t +

Default

$K'_{FM} = K'_{tM} = 1.0$

Reference Atmospheric Pressure

L 0 2 0 | Parm +

MAIN THRUST-WEIGHT TABLE (cont)

Nozzle Parameters

L 011 | Exit Area, A_{eM}

L 013 | ϵ_d | γ_d' | C_D' | α_d

Default $\gamma_d' = 1.18$
$C_D' = 0.96$
$\alpha_d' = 15°$

Motor Internal Ballistic Parameter used on TMC

L 002 | D_p | r_{b1000}

L 095 | ρ_p | τ_w

L 097 | n | α_p | P_{max}

* Note: If $D_p \neq 0$ TMC is assumed default
$\rho_p = 0.065$
$\tau_w = 0.8$
$n = 0.6$
$\alpha_p = 0.00027$

Thrust-Weight Table

L 021 | Time from Ign | Thrust, F_{M1} | Weight Flow, $\dot{W}_{M1}$

L 023 | t_{M2}' | F_{M2} | $\dot{W}_{M2}$

L 026 | t_{M3}' | |

⋮

L 092 | t_{M25}' | |

* Note: If $r_{b1000}' < 0$ F_{Mj} column is used to input chamber pressure

If $r_{b1000}' > 0$ t_{Mj} column is used input web fraction depth and F_{Mj} columns used to input burning surface area

COMPLEMENTARY THRUST-WEIGHT TABLE

Complementary Stage Weight

L 105 | Initial Wt, W_{Co} +

L 107 | No Wt Carry, K_{NO} +

Motor Impulse

L 1C6 | Comp Impulse, I'_{VC} +

L 103 | Sp Imp, I_{spC} +

Multipliers

	Thrust Pert, K'_{FC}	Weight Per, K'_{WC}	Time Pert, K'_{tC}
L 1CC	+	+	+

Default $K'_{FC} = K'_{tC} = 1.0$

Nozzle Exit Area & Reference Atmospheric Pressure

L 104 | Exit Area, A_{eC} +

L 109 | Par C +

Thrust-Weight Table

	Time	Thrust, F_{C1}	Weight Flo, $\dot{W}_{C1}$
L 011		+	+
	t'_{C2}	F_{C2}	$\dot{W}_{C2}$
L 013	+	+	+
	t'_{C3}		
L 016	+	+	+
⋮	⋮	⋮	⋮
	t'_{C25}		
L 082	+	+	+

AXIAL DRAG COEFFICIENT TABLE

Reference Area & Multiplier

	Reference Area, S_{RC}	Perturbation, $\bar{C}$
L 185	+	+

Default $\bar{C} = 1.0$

Mach Number - Coefficient Table

	Mach No, M_1	C_{A1}
L 188	+	+
	M_2	C_{A2}
L 190	+	+
⋮	⋮	⋮
	M_{15}	C_{A15}
L 216	+	+

Tumbling Parameters

	Plan Form Area, S_{PF}	Centroid Plan Form Area, X_{PC}
L 218	+	+

BODY AERODYNAMIC NORMAL FORCE COEFFICIENT TABLE

Reference Area & Multipliers

	Reference Area, S_{RN}	Perturbation, $\tilde{N}$	cp Mult, X_{cp}
L 2 2 0	+	+	+

Default $\bar{N} = 1.0$

$\bar{X}_{cp} = 1.0$

Mach Number, Coefficient, Center of Pressure Table

	Mach No, M_1	C_{N11}	C_{N21}	C_{N31}	x_{cp1}
L 2 2 3	+	+	+	+	+
L 2 2 8	+	+	+	+	+
⋮	⋮	⋮	⋮	⋮	⋮
L 2 ? 3	+ M_{15}	+	+	+	+

AERODYNAMIC DAMPING COEFFICIENT TABLE

Reference Diameter & Multipliers

L 296 | Ref Dia, D_{RN} | Pitch Pert, $\bar{M}_Q$ | Alpha Pert, $M_{\dot{\alpha}}$

+ | + | +

Default $\bar{M}_Q = \bar{M}_{\dot{\alpha}} = 1.0$

Translation Factors

L 301 | Pitch Tran Mult, K_Q | Pitch Moment Pt, x_{RQ} | Alpha Tran Mult, $K_{\dot{\alpha}}$ | Alpha Mom Pt, $x_{R\dot{\alpha}}'$

Mach Number - Coefficients

L 305 | Mach No, M_1 | C_{MQ1} | $C_{M\dot{\alpha}1}$

+ | - | -

L 308 | M_2

+ | - | -

L 347 | M_{15} | C_{MQ15} | $C_{M\dot{\alpha}15}$

+ | - | -

PITCH/YAW CONTROL DATA (cont)

Steering Coefficients (Used in Velocity Steering, ie $T_y = 4$)

L 397 — First Par, σ_{g11} | From K_{g11} | Second Par, σ_{g21} | To K_{g21}

Steering Coefficients, Pitch

L 391 — Const, a_{01} | z Coeff, a_{11} | $\dot{x}$ Coeff, b_{11} | x^2 Coeff, b_{21} | x^3 Coeff, b_{31} | Flare Time, τ_{f1}

Steering Coefficients, Yaw

L 4-1 — Gain, K_{yk} | Vel Coeff, τ_{yk} | Init Vel Int, I'_{gok}

Jet Damping Parameters

L 417 — Forward Prop, x'_{Pf} | Aft Prop, X'_{Pa} | Noz Exit, x'_E

Vehicle Control Respins

L 438 — Veh Dam, ζ_v | Veh Freq, ω_v

Default
$\zeta_v = 0.7$
$\omega_v = f(W_{01})$

Note: If f_{G1} is non zero, gains are automatically calculated from vehicle control response frequency and damping ratio, ie. ω_v & ζ_v

Pitch/Yaw Gains (3 Zones)

Card	Att	Att	Rate	Rate	Bias	Bias			
L 450	K_{DP1}	K_{DY1}	K_{RP1}	K_{RY1}	K_{IP1}	K_{IY1}	f_{G1}	σ_{G1}	K_{G1}
L 459	K_{DP2}	K_{DY2}	K_{RP2}	K_{RY2}	K_{IP2}	K_{IY2}	f_{G2}	σ_{G2}	K_{G2}
L 468	K_{DP3}	K_{DY3}	K_{RP3}	K_{RY3}	K_{IP3}	K_{IY3}	f_{G3}		

ROLL CONTROL DATA

Roll Control Flag

K_{rc}

L 405

If K_{rc} = 1 Auxiliary roll thrusters are used
If K_{rc} = 2 Aerodynamic control fins are used

Disturbing Roll Nozzle Vortex Multiplier

η_{vr} — Default 0.00363

L 436

Initial Roll Control Thrust

Roll F, F_{Ro}

L 424

Roll Control System Response & Gains

Card					
L 638	Lev Arm, l_{R1}	t Const, τ_{R1}	Hyst, D_1	Dead Ba, $F_{\Delta 1}$	Max F_c, L_{Rc1}
L 643	Att Ga, K_{DR1}		Rate Ga, K_{RR1}	I_{spR1}	To time, t_{R2}
L 648	l_{R2}	τ_{R2}	D_2	$F_{\Delta 2}$	L_{Rc2}
L 653	K_{DR2}		K_{RR2}	I_{spR2}	t_{R3}
L 658	l_{R3}	τ_{R3}	D_3	$F_{\Delta 3}$	L_{Rc3}
L 663	K_{DR3}		K_{RR3}	I_{spR3}	

Roll Aerodynamic Fin Mi[illegible]ment Angle & Radial C.P.

δ_{mc} l_{sr}

L 403

PITCH/YAW CONTROL DATA

TVC Vector Point Location

L	Card	V.P. Mult, $\bar{X}_e$	Body Station, x'_e	y Offset, y'_e	z Offset, z'_e
L	430	+	+	+	+

Nozzle Misalignment & TVC Control Flag

L	Card	Pit Mis, δ_{MP}	Yaw Mis, δ_{MY}
L	389	+	+

L	Card	Thrust Flag, K_δ
L	434	+

* If K_δ = 0, TVC is from Main plus Complementary Thrust
If K_δ = 1, TVC is from Main Thrust only
If K_δ = 2, no TVC

Initial Pitch/Yaw TVC Conditions

L	Card	Pitch, δ_{Po}	Rate, $\dot{\delta}_{Po}$	Yaw, δ_{Yo}	Rate, $\dot{\delta}_{Yo}$
L	420				

Staging Tip-off Attitude Rate

L	Card	ΔQ_b	ΔR_b
L	42[illegible]	+	+

Control Limits

L	Card					
L	440	K_{DP} $\Delta\theta_b$ L, L_1 +	δ_{Pc} Lim, L_2 +	δ_P Lim, L_3 +	$\dot{\delta}_P$ Lim, L_4 +	$\ddot{\delta}_P$ Lim, L_5 +
L	445	K_{DY} $\Delta\psi_b$ L, L_6 +	δ_{Yc} Lim, L_7 +	δ_Y Lim, L_8 +	$\dot{\delta}_Y$ Lim, L_9 +	$\ddot{\delta}_Y$ Lim, L_{10} +

Dither

L	Card	Dit Amp, A_L	Steer Fac, $K'_\wedge$	Dit Freq, ω_L
L	386	+	+	+

TVC System Transfer Function Characteristics

L	Card	t Const, τ_c	Dam Rat, ζ_c	Freq, ω_c
L	435	+	+	+

CENTER-OF-GRAVITY AND INERTIA DATA

Multiplier and Lars Factor

L 475	I_Y Mult, $\bar{I}_Y$ +	I_Z Mult, $\bar{I}_Z$ +	I_X Mult, $\bar{I}_X$ +	
L 478	Weight Mult, W +	x_{cg} Mult, $\bar{X}_{cg}$ +	z_{cg} Bias, z_{cg} +	y_{cg} Bias, y_{cg} +

Weight versus C.G. and Inertia about C.G.

	Total Wt, W_1	Miss cg, x_{cg1}	Pit, Inertia, I_{Y1}	z offset, z_{cg1}	Yaw Inertia, I_{Z1}	y offset, y_{cg1}	Roll Inertia, I_{X1}
L 488	+	+	+		+		+
L 498	+	+	+		+		+
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
L 628	W_{15} +	+	+		+		+

AERODYNAMIC ROLLING MOMENT COEFFICIENT TABLE

(Due to Raceway)

Raceway #1 Data

	Ref Area 1, S_{RR1}	cp Rad Loc 1, r_{R1}	Roll Ang 1, φ_{R1}
L 6 6 7	+		+

Raceway #2 Data

	Ref Area 2, S_{RR2}	cp Rad Loc 2, r_{R2}	Roll Ang 2, φ_{R2}
L 6 7 0	+	+	+

Mach Number versus Coefficient

	Mach No., M_1	Roll Coef, C_{RR1}
L 6 7 3	+	
	M_2	
L 6 7 5	+	
⋮	⋮	⋮
	M_{10}	
L 6 9 1	+	

AERODYNAMIC MOVABLE CONTROL FIN TABLE

Fin Geometry

Card	Fin Area, S_{Fz}	Hinge Pt B.S. x_{bz}	Fin Hinge Pt, U_{hz}	Root Chord length, l_{hz}
L 7 0 0				

Deflection Angle Multipliers

Card	Yaw fin, K_{ycf}	Pitch fin, K_{pcf}
L 7 0 4		

Coefficient Multipliers

Card	Lin. Lift Mult C_{1z}	Non Lift Mult C_{1z}	Drage Mult C_{Dz}	Drag D.T. Lift Mult, K_{1z}
L 7 0 6				

Default $\bar{C}'_{Lz} = \bar{C}'_{1z} = \bar{C}'_{Dz} = \bar{K}'_{Lz} = 1.0$

Mach Number versus Coefficients

Card	Mach No.					
L 7 1 0	M_1	C_{Lz1}	C_{1z1}	C_{Dz1}	K_{Lz1}	U_{cz1}
L 7 1 6	M_2					
⋮	⋮	⋮	⋮	⋮	⋮	⋮
L 7 9 4	M_{15}	C_{Lz15}	C_{1z15}	C_{Dz15}	K_{Lz15}	U_{cz15}

AERODYNAMIC COEFFICIENTS

Executive Control Card
Column 10 Equal 1

Body Description

BS_1 BD_1

L 500+ +

BS_2 BD_2

L 502+ +

* Note: Body is described as a combination of frustrum of cones (bodies of revolutions)

BS_{21} BD_{21}

L 540+ +

All linear dimensions are in inches, areas are in square inches

Separation Planes

BS, Sep 1 BS, Sep 2 BS, Sep 3

L 542+ + +

Nozzle Exit Areas (in square inches)

Ae_1 Ae_2 Ae_3 Ae_4

L 548+ + + +

BD Ref R_N Input Code

L 554+ +

R_N Input Code

1 = Small 2 Stage Ballistic Missile
2 = Large 3 or 4 Stage Ballistic Missile
3 = Large Booster Vehicle
4 = Small Air Launched Missile

AERODYNAMIC LIFTING SURFACES

Control Surfaces

Executive Control Card
Column 12 Equal 1

CANARD

		x_{or}	c_R
L 560+		+	+
	ϵ_L	λ	τ
L 563+		+	+
	x_H	r_b	ρ
L 566+		+	+

FIN

		x_{or}	c_R
L 572+		+	+
	ϵ_L	λ	τ
L 575+		+	+
	x_H	r_b	ρ
L 578+		+	+

x_{or} = Body Station root chord leading edge

c_R = Root chord length

ϵ_L = Sweep angle

λ = Taper ratio

τ = Thickness ratio

x_H = Hinge line body station

r_b = Ave body radius

ρ	Code
0	Aluminum
1	Steel

Executive Control Card
Column 14 Equal 1

ROLL CONTROL REQUIREMENT

Mandatory

Opt. Data Flag, K_{tr}

L700 +

If K_{tr} is non-zero, $C_{N\alpha}$, $q_{\alpha m}$, δ_{mx} are obtained from Trajectory Calculated Values

Required Default	Default from Duty Cycle
Stage No., K_k — L701 +	= L7027
Case Dia, D_B, in — L702 +	= L7028
Stg Vac Thrust, F_{vac} — L703 +	= L7031
Stg Liftoff W_t, W_o — L704 +	= L7032
Veh Vac Thr/W_t, F_{vac1}/W_{o1} — L705 +	= L7029
Aero N Force, $C_{N\alpha}$ — L706 +	= L7024

Override Curve Fit

Max $q\alpha$, $q_{\alpha m}$

L707 +

Max δ, δ_m

L708 +

Offset, ϵ_{os}

L709 +

PUNCH DUTY CYCLE

EXECUTIVE CONTROL CARD
COLUMN 16 EQUAL 1

THE TVC DUTY CYCLE DATA IN THE REGION L7000 THROUGH L7799 IS PUNCHED

AERODYNAMIC LOADING DISTRIBUTION

Executive Control Card
Column 18 Equal 1

L500 through L555	The data describing the body of revolution in the AERODYNAMIC COEFFICIENTS region must be input.

The following duty cycle data must be available:

L7021	$q\alpha'_{max}$	Product of maximum absolute value of q and α
L7022	$q_{q\alpha'}$	q at maximum $q\alpha'_{max}$
L7024	$C_{N\alpha q}$	Aerodynamic normal force coefficient at maximum $q\alpha'$
L7025	$M_{q\alpha}$	Mach Number at maximum $q\alpha'$
L7027	K_{dc}	TVC stage number
L7052	$h_{q\alpha'}$	Altitude at maximum $q\alpha'$
L7053	$P_{q\alpha'}$	Atmospheric pressure at maximum $q\alpha'$
L7057	$\alpha_{q\alpha'}$	Angle of attack at maximum $q\alpha'$
L7058	$\beta_{q\alpha'}$	Angle of side slip at maximum $q\alpha'$

SER'S AID

FOR

NOZZLE AND PINTLE NOZZLE SUBROUTINES

MANDATORY NOZZLE PROGRAM INPUT

(WHEN USED WITH TRAJECTORY)

NO PINTLE NOZZLE DESIGN

1. CONTROL CARD

2. NOZZLE

·NOZZLE AND TVC TYPE	L0-L3 (THREE)
·THROAT SIZE	L10-L13 (ONE)
·EXPANSION RATIO	L17-L18 (ONE)
·OPERATING TIME	L19
·CHAMBER PRESSURE	L20
·VECTOR ANGLE	L21

3. LITVC OR HOT GAS INPUT AS REQUIRED

MANDATORY NOZZLE PROGRAM INPUT

(WHEN USED WITH TRAJECTORY)

PINTLE NOZZLE DESIGN

1. CONTROL CARD

2. NOZZLE

   - NOZZLE AND TVC TYPE L0-L3 (THREE)
   - VECTOR ANGLE L21

3. LITVC OR HOT GAS INPUT AS REQUIRED

4. PINTLE NOZZLE

   - PNOZ - PINTLE NOZZLE DESIGN CONTROL L40

DESIGNATOR NUMBERS (DESIG) VALID

FOR PINTLE NOZZLE DESIGNS

241	300	441	741
251	310	---	751*
252	324	541	752*
253	325	562	753*
262	326	563	762*
263	330	---	763*

*AN A OR B WILL BE SUFFIXED BY THE PROGRAM. A INDICATES A NEGATIVE EJECTION LOAD (BLOWIN LOAD). B INDICATES A POSITIVE EJECTION LOAD (BLOWOUT LOAD).

MANDATORY NOZZLE PROGRAM INPUT

(WHEN USED WITHOUT TRAJECTORY)

NO PINTLE NOZZLE DESIGN

1. CONTROL CARD

2. DUTY CYCLE

·NO. OF DUTY CYCLE POINTS	L7046
·DUTY CYCLE TIME POINTS	L7100+
·DELIVERED THRUST	L7400+
·VACUUM THRUST	L7600+
·WEIGHT FLOW RATE	L7700+

3. NOZZLE

·NOZZLE AND TVC TYPE	L0-L2 (THREE)
·THROAT SIZE	L10-L13 (ONE)
·EXPANSION RATIO	L17-L18 (ONE)
·OPERATING TIME	L19
·CHAMBER PRESSURE	L20
·VECTOR ANGLE	L21

4. LITVC OR HOT GAS INPUT AS REQUIRED

MANDATORY NOZZLE PROGRAM INPUT

(WHEN USED WITHOUT TRAJECTORY)

PINTLE NOZZLE DESIGN

1. CONTROL CARD

2. DUTY CYCLE

·NO. OF DUTY CYCLE POINTS	L7046
·DUTY CYCLE TIME POINTS	L7100+
·DELIVERED THRUST	L7400+
·VACUUM THRUST	L7600+
·WEIGHT FLOW RATE	L7700+

3. NOZZLE

·NOZZLE AND TVC TYPE	L0–L3 (THREE)
·VECTOR ANGLE	L21

4. LITVC OR HOT GAS INPUT AS REQUIRED

5. PINTLE NOZZLE

   (CONTINUED)

MANDATORY NOZZLE PROGRAM INPUT

(WHEN USED WITHOUT TRAJECTORY)

5. PINTLE NOZZLE (CONTINUED)

·PNOZ - PINTLE NOZZLE DESIGN CONTROL	L40
FMAX - MAXIMUM THRUST LEVEL	L42
PCMAX - CHAMBER PRESSURE AT FMAX	L43
EPSMAX - EXPANSION RATIO AT FMAX	L44
FMIN - MINIMUM THRUST LEVEL	L46

OR

FMIN - MINIMUM THRUST LEVEL	L46
PCMIN - CHAMBER PRESSURE AT FMIN	L47
EPSMIN - EXPANSION RATIO AT FMIN	L48
FMAX - MAXIMUM THRUST LEVEL	L42

PINTLE NOZZLE CONTROL PARAMETERS

L-NO.	TERM	CONTROLS	STORED VALUE	TYPE OF INPUT
40	PNOZ	PINTLE NOZZLE DESIGN	0	MAND.
		0 - NO DESIGN		
		1 - DESIGN		
41	PTYE	TYPE OF PINTLE	*C	OPT.
		1 - SOLID TUNGSTEN		
		2 - TUNGSTEN SHELL		
		3 - ABLATIVE SLEEVE		
55	EXT	MOTOR EXTINGUISHMENT DESIGN	0	OPT.
		0 - NO DESIGN		
		**1 - DESIGN		
80	GTYPE	GRAIN TYPE	2	OPT.
		1 - CONSTANT SURFACE AREA		
		***2 - VARIABLE SURFACE AREA		

*VALUE IS CALCULATED.

**IF EXT = 1, L50, ATEXTA, MUST BE INPUT.

***IF GTYPE = 2, L92, ATMXA, AND L93, ATMNA, MUST BE INPUT.

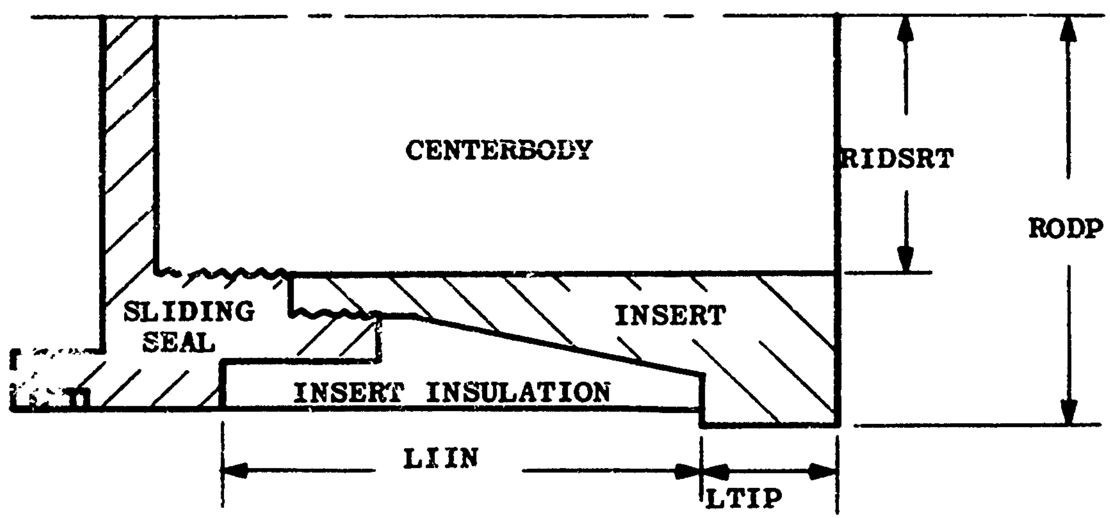
OPTIONAL INPUT FOR TUNGSTEN SHELL PINTLE

SYMBOL	DEFINITION	SAFETY FACTOR	MATERIAL CODE	INSULATION* OR STRUCTURE	WEIGHT	L-NO. OF SAFETY FACTOR
P T	PINTLE				--	
SRT	INSERT	1.25	6	I	--	L1399
IIN	INSERT INSULATION	1.50	7	I	--	L1402
CB	CENTERBODY	1.50	1	I	--	L1405
SS	SLIDING SE[illegible]	1.25	12	S	--	L1408

*I MEANS THE MATERIAL SPECIFIED BY THE MATERIAL CODE IS FOUND IN THE INSULATION MATERIALS TABLE.

S MEANS THE MATERIAL IS FOUND IN THE STRUCTURAL MATERIALS TABLE.

COMPUTER OUTPUT



TUNGSTEN SHELL PINTLE

TUNGSTEN SHELL PINTLE DIMENSIONS

L-NO.	SYMBOL	DEFINITION	VALUE	UNITS
	RODP	RADIUS TO OUTSIDE DIAMETER OF PINTLE	--	IN.
L1087	RIDSRT	RADIUS TO INSIDE DIAMETER OF PINTLE INSERT	--	IN.
	LPTIP	LENGTH OF PINTLE INSERT TIP	--	IN.
	LIIN	LENGTH OF INSERT INSULATION	--	IN.

COMPUTER OUTPUT

ADDITIONAL OPTIONAL INPUT TO WATCH

- PROPELLANT PROPERTIES

  L7, AND L34-L38 (NOZZLE SUBROUTINE)

  L1076 (PINTLE NOZZLE SUBROUTINE)

- NO. OF CENTERBODY STRUTS AND STRUT ANGLE

  L1070 AND L1071

- PINTLE TIP BALANCING AREA

  L1075

- DISCHARGE COEFFICIENTS

  L1077-L1079

- PINTLE EROSION RATES

  L1080 AND L1081